

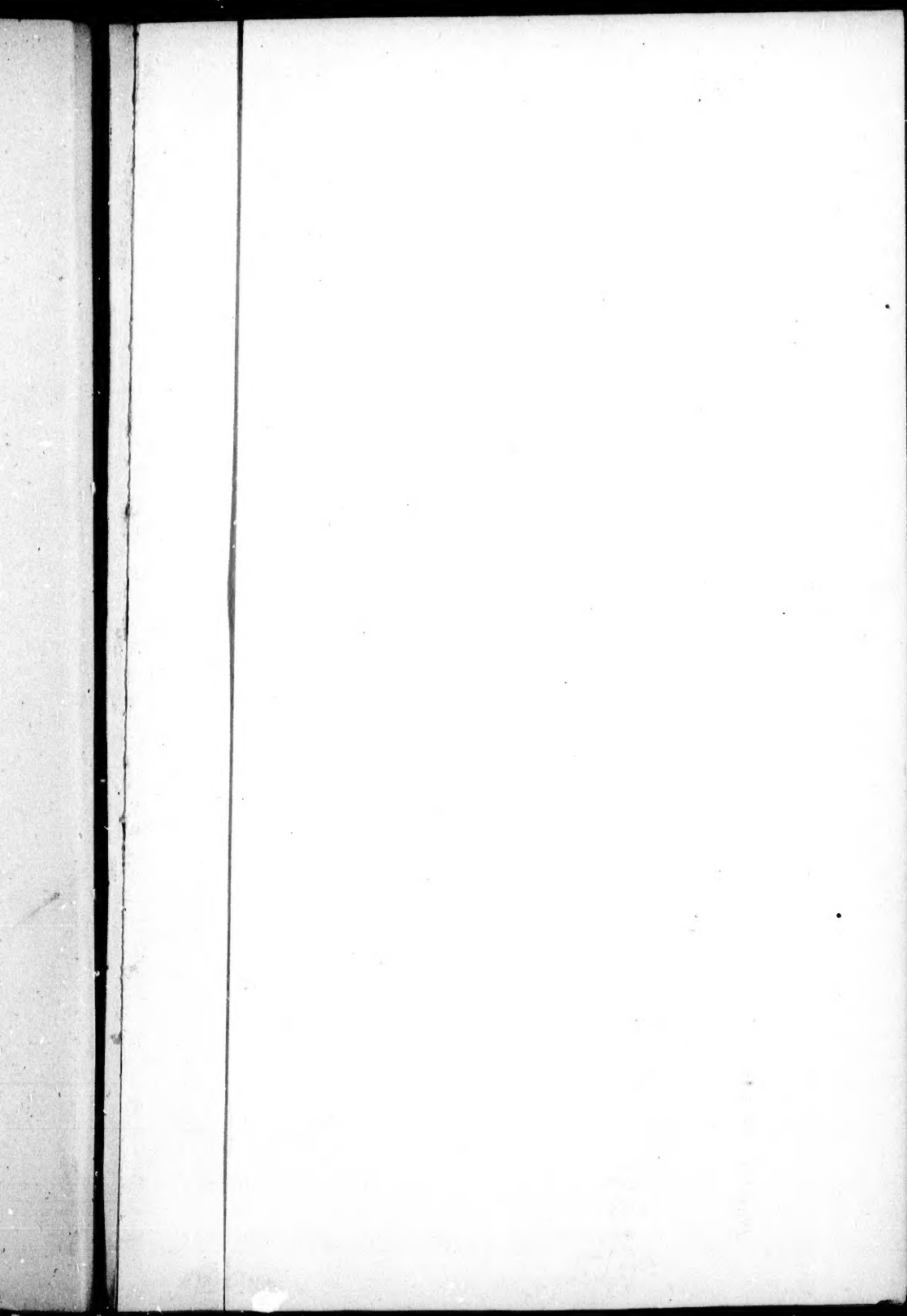
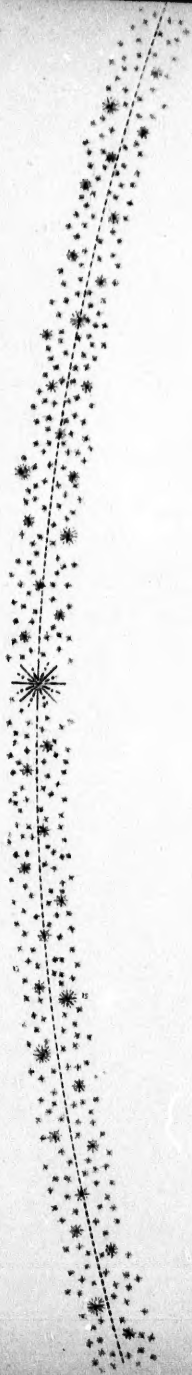
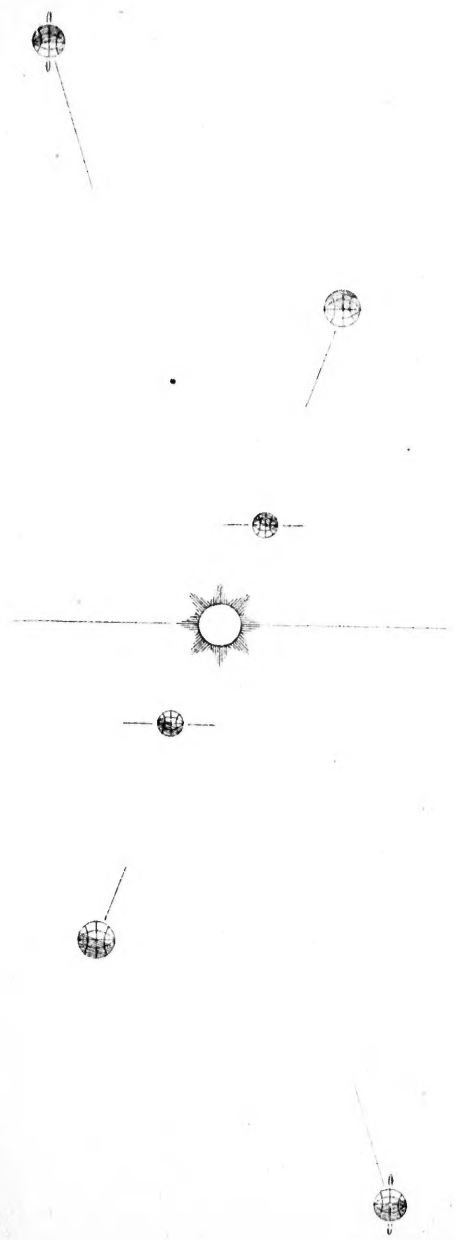


Plate 6. (Fig. 10)



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Axis of Earth





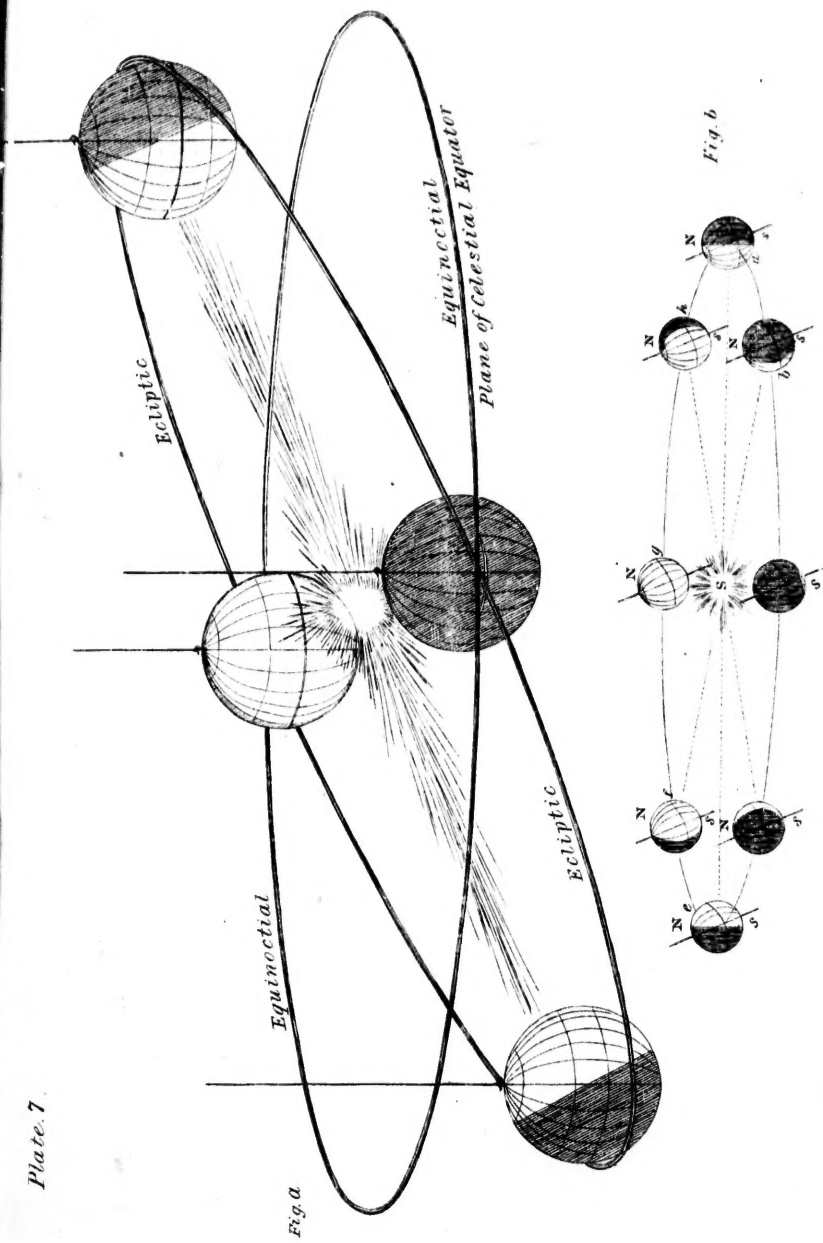


Fig. a. Illustrating the theory of the Perpendicular Axis.

Fig. b. Illustrating the theory of the Inclined Axis.

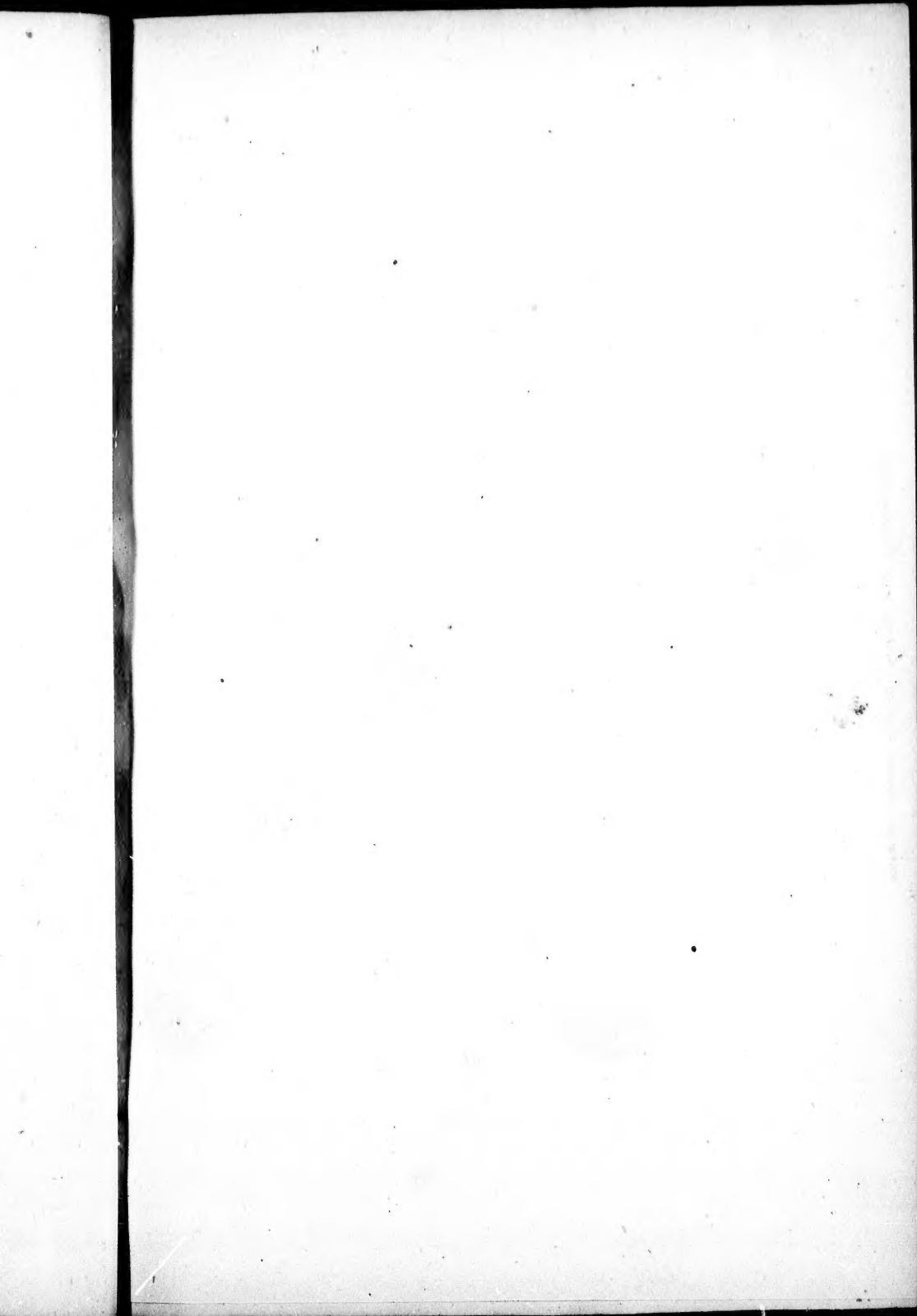
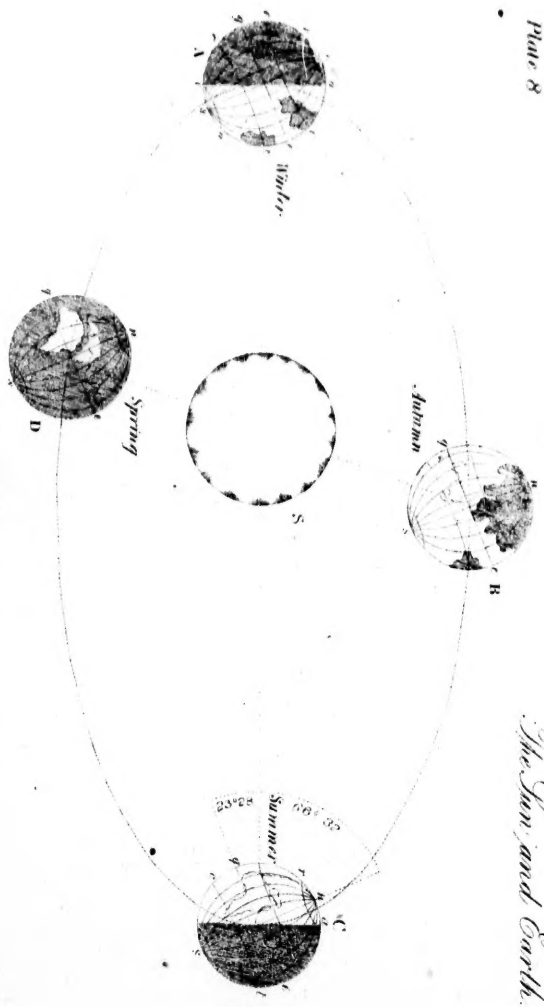




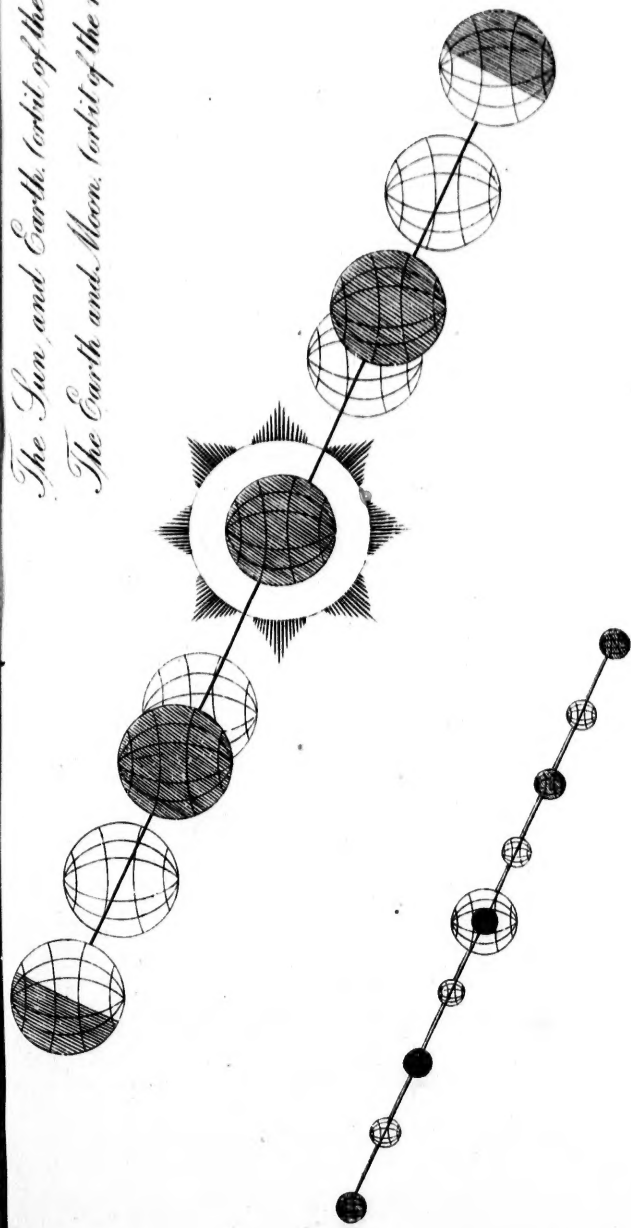
Plate 8

The Sun, and Earth.



Illustrating the theory of the inclined axis

The Sun, and Earth. (orbit of the earth.)
The Earth and Moon. (orbit of the moon.)



Illustrating the theory of the perpendicular axis.

(2.)

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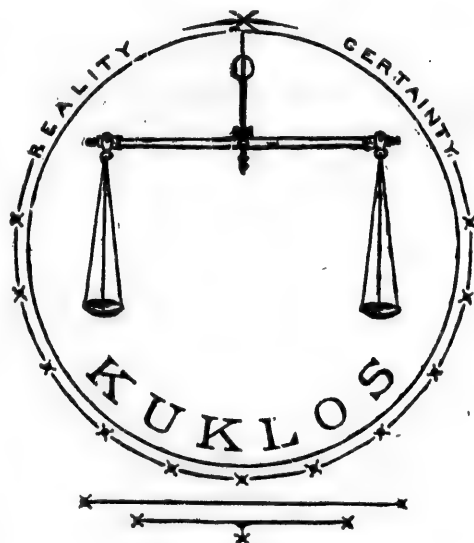
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(2.) CENTRIFUGAL FORCE & GRAVITATION.

THEORY
OF
ORBITAL REVOLUTION.

DEMONSTRATION OF
THE EARTH'S PERPENDICULAR AXIS
AND
OBLIQUE PLANE OF TERRESTRIAL ORBIT.

BY
JOHN HARRIS.



~~Mercantile~~

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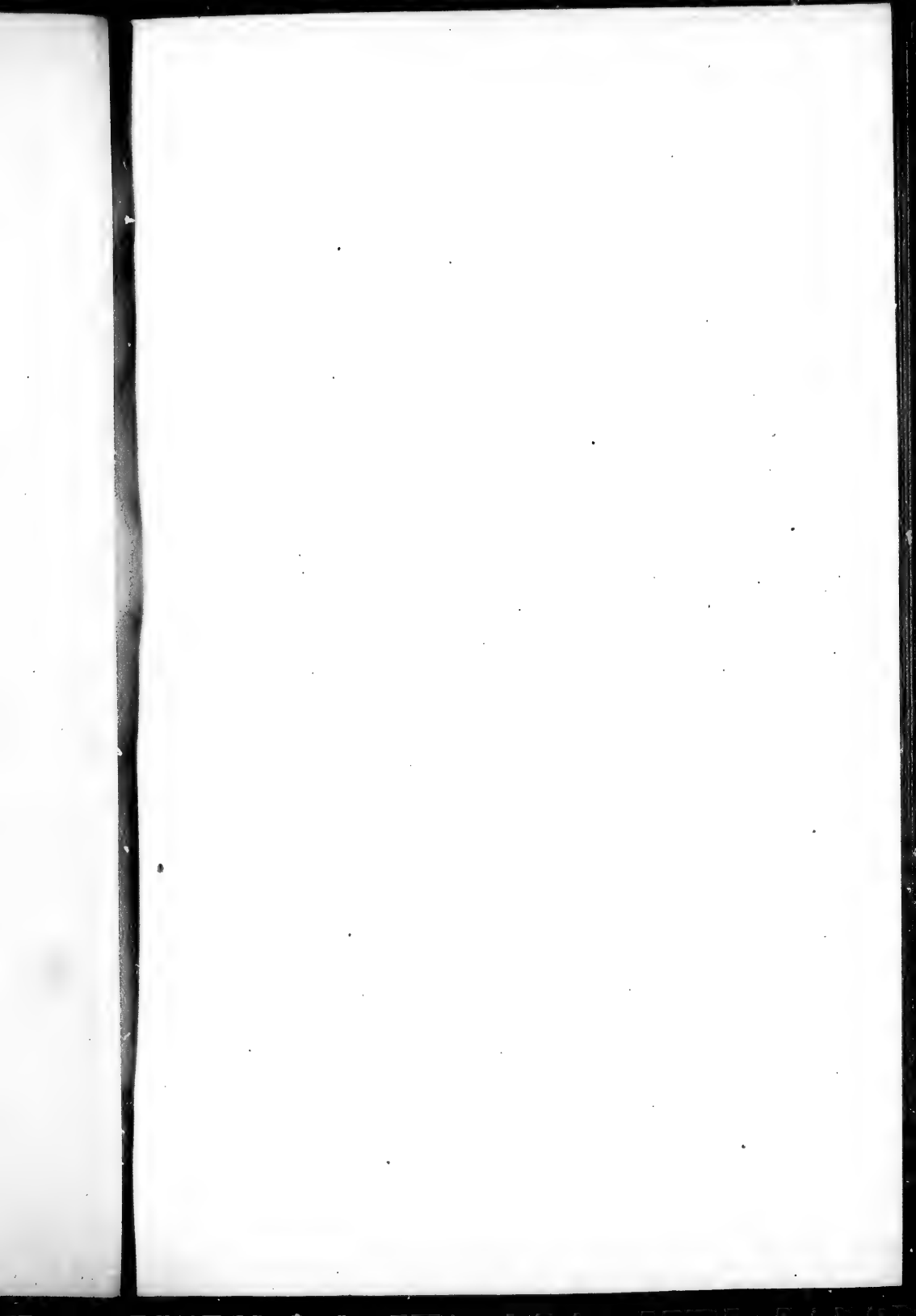
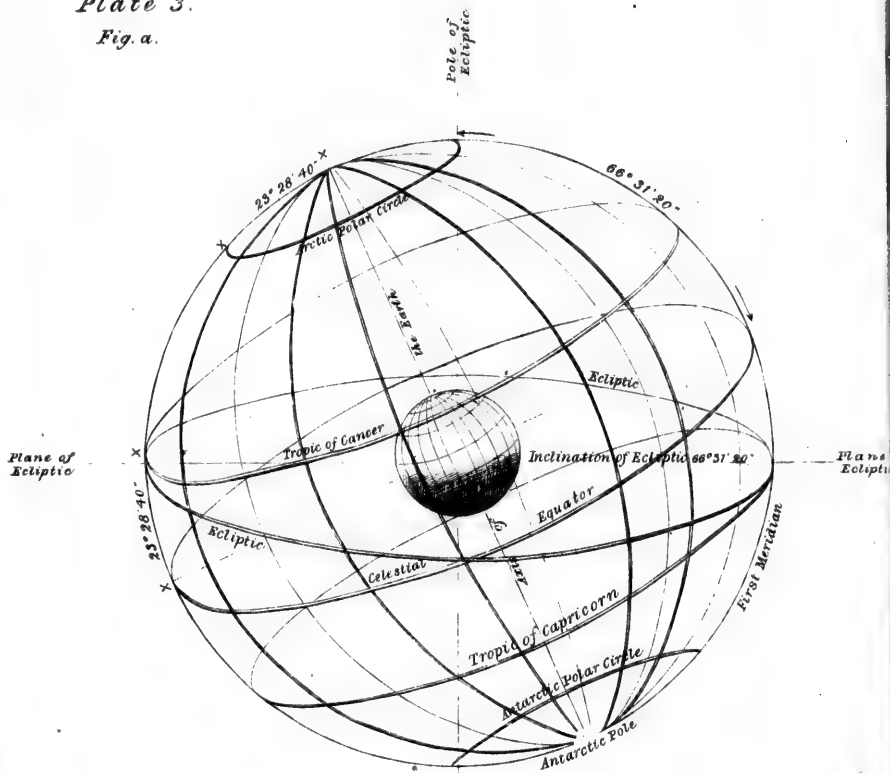


Plate 3.

Fig. a.

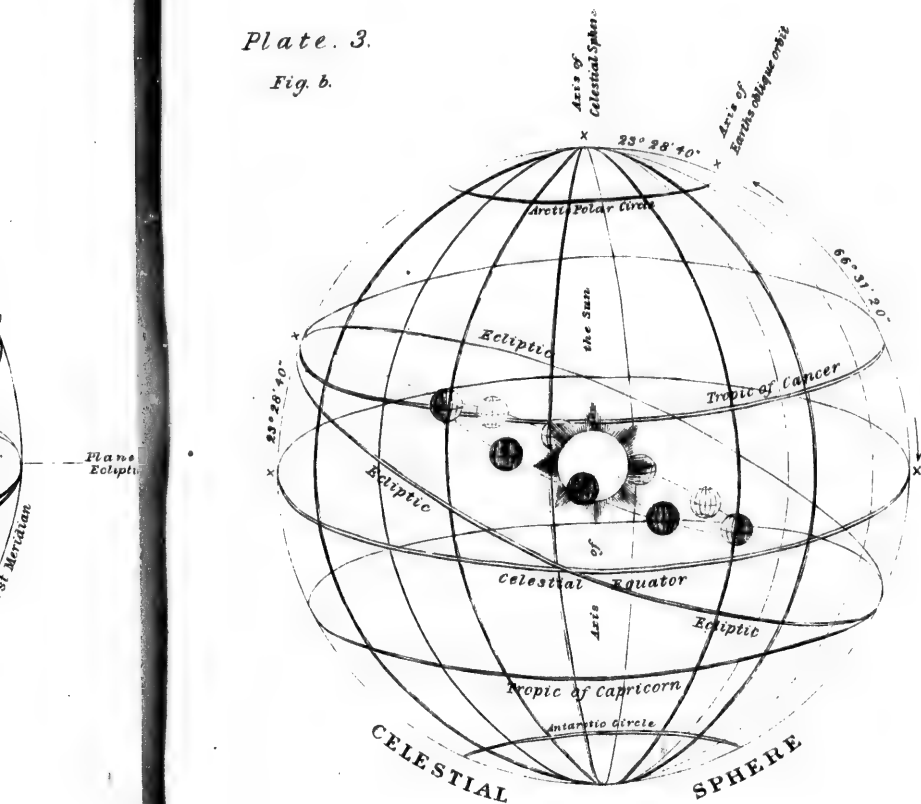


Theory of Inclined Axis.

From A.K Johnston's
Atlas of Astronomy.

Plate. 3.

Fig. b.



Theory of Perpendicular Axis.

INTRODUCTORY OBSERVATIONS AND DEFINITION.

(1) ON THE CELESTIAL SPHERE AND THE RELATIVE POSITION OF THE SOLAR SYSTEM.

When the heavens are surveyed by an inhabitant of the earth, the appearance is presented of a gigantic sphere upon the interior concave surface of which the stars are projected, and of which the centre is occupied by his station—the earth.

When the astronomer . . having discovered that certain of the bodies occupying this apparent sphere, namely—the sun and planets, were much nearer to him and, dynamically, were more closely related to the earth, upon which he is stationed, than the other occupants . . became aware that the earth was a member of a particular system to which they also belonged, his first idea was that the earth was the central body of this system, and that the other members (of this *terrestrial* system) revolved around the earth. This theory, based as it was upon crude and, to some extent, erroneous observations of the apparent phenomena, became extremely complicated, as the facts of observation, with which it was necessary to reconcile and harmonize the theory, increased in number.

After a time it was suggested that the sun and not the earth might probably be the central and controlling

member of the system. Careful examination and advanced experience demonstrated this theory of a *Solar System* to rest upon reality and fact. . . and the theory of a *Terrestrial System*, no longer tenable, was quite given up as false and unsound.

Nevertheless, to the terrestrial observer the sun and not the earth appears to move ; and it may be said :— Since we know and are sure that, in fact, the earth moves round the sun and not the sun round the earth, we may still, for convenience in explaining certain astronomical phenomena, assume that the sun moves as it appears to do, keeping in mind, of course, that such assumption is, strictly speaking, not true in fact, and limiting the fiction to those cases where it cannot vitiate the conclusion or result. This plan is accordingly pursued in certain cases at the present time, but every astronomer and student of astronomy is supposed to distinctly apprehend, as fact, that the sun and not the earth is the central and governing body of the system to which both belong.

Let us now return to the observer who, surveying the heavens without the knowledge of astronomy gained by experience, and misapprehending the phenomena, inferred that his station—the earth, was the centre of the celestial sphere. Having by subsequent investigation ascertained that, beyond doubt, the sun, and not the earth, is the central governing member of the Solar System, does he, in correspondence and harmony therewith, put the sun instead of the earth in the centre of his *ideal* celestial sphere ? And, if not—why does he not do so ?

It is true the astronomer has now no evidence that the sun occupies the centre of the stellar universe ; on

the contrary, there are reasons why he infers that our sun is the centre of one system only, and that there are many other similar systems, each having its own centre of gravitation, and together having, perhaps, one great central sun around which all revolve in regulated and connected order.

But in this case, as in every other, if we endeavour to deal with absolute space or infinitude, as such, we stultify ourselves and make no progress. The Solar System is astronomically our immediate universe: with it, the domain to which we particularly belong and which particularly belongs to us, we have to make ourselves correctly acquainted. Having done so, and thus acquired a firm and secure station, we shall be in a position to look further with confidence in the endeavour to discover what is beyond.

As evidence that the necessity of defining the relative position in space of our station is practically admitted, we may remark that the globe, whether celestial or terrestrial, is always represented and considered as having an upper and under part and as having sides; for the north polar region is considered the upper part, and the east and west the sides; nevertheless, the inhabitants of the southern hemisphere would naturally object to an inference that they are constantly standing with their heads downwards.

In the argument which is the subject of this book* we have to deal, according to our view, with an unsound theory, irreconcilable with the observed facts, and resulting from a false compound assumption:—

* This book is the second part of the series entitled "Centrifugal Force and Gravitation," but its own subject is distinct and particular to itself.

i. e., of several false assumptions combined together. But, according to the doctrine now held, the assumption is looked upon as a conclusion arrived at by, or through, the theory, whilst the theory itself is supposed to be based upon the facts of astronomical observation.

Now since our argument, which has to do with the relative positions and motions of those bodies which collectively constitute the solar system, is closely related to a correct apprehension of the celestial sphere, it is important that we should, at the outset, guard our statements against the risk of the misapprehension which would be likely to arise from a confused or indefinite use of the descriptive terms now applied to the various parts of the celestial sphere. The importance and necessity of such preliminary care is in this particular case, according to our view, unusually great, because it is precisely a want of sufficient attention to definiteness which, if it has not originated the error we purpose here to point out, has greatly assisted to confirm and build it (so to speak) into the fabric of astronomical science.

To state in this place our definition of the celestial sphere, and insist upon its correctness, would be, in some measure, to prejudge that case which is the subject of our argument; but we find that the general definition, or, more correctly speaking, the general meaning now attached to the celestial sphere does not harmonize with itself in a strict sense (to wit, one part does not agree with the other parts of it); the theoretical astronomer attaching a certain meaning and value to the descriptive terms belonging to it, hands it over to the practical astronomer who, misapprehending the precise meaning and value which has been attached to those terms, immediately and unawares alters the position of

the sphere to bring it into harmony with his facts. The consequence is that a fallacy of a very grave and important character, which would otherwise make itself apparent, remains undetected.

What we, therefore, find it necessary to do, in the first instance, to preserve our argument from unnecessary complexity and risk of misapprehension, is to amend the definition of the celestial sphere belonging to the doctrine now taught and accepted, namely, to bring the definition of the terms into harmony with the doctrine to which they belong. At the same time, our argument is by no means dependent on any particular descriptive terms or expressions; any other definition, if it be supported by the known facts, if it be distinct and be strictly adhered to, may be adopted in preference and our argument be adapted to it.

The positive definition of the value now generally attached by astronomers to those expressions, as stated by Sir John Herschel in his work '*The Outlines of Astronomy*' will be found in the Appendix, (at the end of the book,) to which the reader is referred.

Reference will show that the equatorial plane of the celestial sphere is defined to be coincident with the equator of the earth. Now such definition in this particular is inconsistent with the general doctrine or theory of the celestial sphere, as in other respects taught at the present time and accepted by Sir John Herschel and other astronomers, for the earth travels around the sun and, by this definition, the equator of the celestial sphere is an extension of the earth's equator in whatever part of its orbit the earth may be; but the fundamental assumption of the theory is that the earth's axis is inclined, conse-

quently, if it be not admitted that the definition is in this particular false, it will follow that Sir John Herschel believed the Ptolemaic and not the Copernican theory to be in accordance with fact, because, if the sun travel around the earth, or if he move his position relatively to a fixed earth, actually or theoretically, all the other heavenly bodies must do so likewise.

Wherefore, it is evident that the present doctrine, to be made consistent with itself, requires that the sun's axis be considered coincident with the axis of the celestial sphere, and the earth's equator be considered oblique to the celestial equator (as shown in our plates, figs. 22 and 23, illustrating the theory of the inclined axis). For the purpose of this work we therefore amend the definition accordingly, and will consider such to be the accepted definition belonging to the doctrine of the celestial sphere and inclined axis of the earth, as now taught.

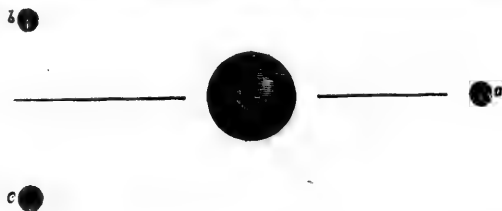
(2) THE THEORY OF THE EARTH'S PERPENDICULAR AXIS.

In considering the orbital revolution of the earth and of other planets around the sun, we have seen that the motion of these bodies are controlled and regulated by the two opposing forces . . the attractive force of gravitation and centrifugal force. We have seen that so complete is the controlling and restraining influence thus conferred on the great centre of gravitation—the sun—that, even if a planet were to be, by the perturbing effect of some outside influence, temporarily caused to deviate from its allotted orbit, so soon as the interfering influence were withdrawn the irregularity would be found inconsistent with the law of equilibrium, and the planet be compelled to return to the appointed orbit.

Thus far, therefore, with respect to the motion of a

planetary body around the sun in a circular orbit, the explanation is intelligible and satisfactory;* but, for the arrangement to possess the characteristics of permanence and stability, there is vertical motion in the orbital path to be provided for, and to be limited, regulated, and controlled by some counteracting force corresponding in the nature of its office to that force which restrains deviation of the body from its orbit in the horizontal direction. The necessity of a restraining force to counteract vertical deviation may be at once appreciated by reference to fig. 1, wherein a planet is supposed to revolve around the sun in the plane of the sun's equator at *a*. Now, why should the planet continue precisely in that plane unless there be some force to restrain its deviation therefrom, and if it deviate at all, even in the least degree, why should not such deviation continue and become augmented unless there be some limiting and controlling influence actually exerted to prevent it from so doing? Why, for example, when the planet, revolving at *a* in the plane of the sun's equator, arrives at the opposite extremity of the orbit, may it not be found much above that plane as at *b*, or much below it as at *c*?

Since, therefore, a restraining force is evidently need-



* But the orbit is found to be not circular but elliptical, and herein is an independent case of which the present doctrine does not furnish satisfactory explanation.—See last Section—*The Solar System*, &c.

ful for this purpose, and must necessarily be in operation to secure the stability and regularity of the orbital motion. . . What is that force? What are its characteristics? Whence is it derived?

The question at once suggests itself whether it be an additional application of the same gravitative (attractive) force, or whether it be some force other than gravitation.

Now (1) whether there actually be, or not, a vertical deviation from the horizontal plane, *i. e.*, an ascent above and a descent below that plane, must be determinable by the observed facts of astronomy; and (2) if such deviation be demonstrable, and it be clearly shown that the attractive force of gravitation affords a sufficient means of regulating, limiting, and controlling that deviation, it will be unnecessary and unphilosophical to seek for any other cause.

The full and satisfactory answer to the above question is contained in the theory of the earth's perpendicular axis, which we will now proceed to explain. . . putting the theory in the first instance in the form of a proposition; and which proposition we purpose to demonstrate by the observed and established facts of astronomy, after having explained the particular characteristics of the theory.

Compound Affirmative Proposition.

(1) That the polar axis of the sun is coincident (and identical) with the polar axis of the celestial sphere.

(2) That the polar axis of the earth is parallel to the polar axis of the sun; and, consequently, is perpendicular to the equatorial plane of the celestial sphere in an astronomical sense:—*i. e.*, the *ideal* celestial sphere of the terrestrial observer (inhabitant of the solar system.)

(3) That the circle and plane, known as the ecliptic and plane of the ecliptic, is, in fact, the oblique orbit.. the circle being the projection, and the plane of the ecliptic—the plane, of that oblique orbit..travelled through by the earth, in its annual revolution around the sun.

(4) That the obliquity of the earth's orbit is caused by the vertical motion of the earth compounded with the motion belonging to the horizontal revolution, which horizontal motion alone would be coincident with or parallel to the equatorial plane of the sun.

(5) That the equinoctial circle is coincident with the equator of the celestial sphere (*i. e.*, also, with the equatorial plane of the sun).

(6) That the total (apparent) vertical distance moved through by the earth is 47 degrees*..viz., $23\frac{1}{2}^{\circ}$ above and $23\frac{1}{2}^{\circ}$ below the plane of the sun's equator.

(7) That the attractive force of the sun's gravitation limits the vertical motion of the earth, restraining its motion from exceeding the limit and causing it to return towards the equatorial plane. And that the diurnal rotation of the earth on its polar axis ensures the constant perpendicularity of that axis.

The general application of this theory, or, more correctly speaking, the harmony of the theory with the facts of which it is presumptively the exponent may be shown by following the earth throughout one complete annual revolution.

* At the conclusion of the argument we shall give some reasons for supposing the *actual* vertical distance moved through by the earth to be 45 degrees.

The Oblique Compound Orbit.

Fig. 8, Plate 5.—We will commence with the winter solstice; the earth being then at *m*. its maximum elevation above the plane of the sun's equator, a line joining the centre of the earth and the centre of the sun, at this place, forms with that plane an angle of about $23\frac{1}{2}$ degrees. Since the distance of the earth from the sun is known, we can easily obtain the approximate value of the $23\frac{1}{2}$ deg. of vertical deviation at that distance. Taking the distance roughly at 95 million miles we have $95,000,000 \times (6 \div 15) =$ about 37,255,000 miles* as the maximum elevation of the earth's centre above the plane of the ecliptic.

The theoretical condition of the earth, so situated, in respect to solar illumination and its consequences, will be, as illustrated by the figure, precisely that which is known to be the actual condition. The arctic circle will be unilluminated; the antarctic circle constantly illuminated. To the Southern regions it will be summer; because the days will be longer, the rays of the sun will strike the earth almost vertically, and those parts of the earth will also be the nearest to the sun. To the Northern regions it will be winter;—the days being shorter, and the rays of the sun falling very obliquely on those parts of the earth, which will also be the most distant from the sun.

When the longitude of the sun has increased 30° , that

* Since the sine of the arc, and not the arc itself, should be taken, the vertical distance from the horizontal plane would be a little less; and, supposing this to be the place of least horizontal distance from the sun, the vertical elevation should be diminished accordingly. The figures above are merely given tentatively as a rough approximation to illustrate the case.

is when the earth has advanced 30° in its orbit (to the first point of Leo) the elevation of the earth above the plane of the sun's equator will have decreased by one third, and will be therefore

$$37,255,000 - 12,418,333 = 24,836,667 \text{ miles.}$$

The days, in the Northern regions of the earth, will have become proportionally longer, and, in the southern regions, shorter.

A second advance of 30° in its orbit reduces the earth's deviation to $24,836,667 - 12,418,333 = 12,418,333$ miles; and a third advance of 30° , which completes the quadrant, brings the earth's equator to the plane of the sun's equator, The earth has then arrived at the vernal equinox, and the days and nights will be of equal duration in both hemispheres.

But the earth continues to descend, as the orbital motion proceeds, and, passing the plane of the sun's equator, arrives, when another advance of 30° in the orbital path has been completed, at a distance below that plane of 12,418,333 miles. When the second quadrant has been completed, the descent of the earth below the plane of the ecliptic will be a distance of 37,255,000 miles, equal to the elevation above that plane at the opposite extremity of the orbit.

The conditions of solar illumination on the earth's surface compared to those first considered, are now reversed. . . . The arctic regions experience a continual day; the antarctic a continual night; to the northern parts of the earth it is now the season of summer; to the southern parts the season of winter. The maximum depression of the earth's equatorial plane below that of the sun has been now attained, and the

earth, after making a brief pause in its vertical motion, commences to re-ascend ; on completion of the third quadrant, the centres of the earth and the sun are again in the same horizontal plane, and the autumnal equinox has been arrived at.

The ascent of the earth still continuing, the plane of the sun's equator is again passed, and, when the orbital revolution has been completed, the earth has arrived at the plane first considered (viz., the winter solstice) and has again attained the maximum elevation of 37,255,000 miles above the plane of the sun's equator.

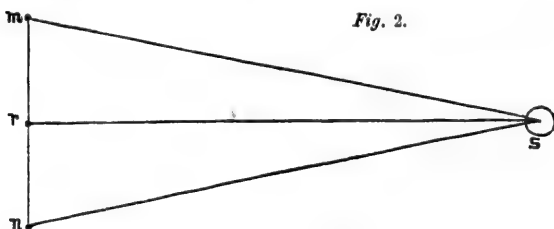
For the sake of simplifying the explanation, in the first instance, we have here considered the velocity of the earth's vertical motion uniform throughout, but this, evidently, cannot be the actual relation between the vertical and horizontal motions : for, at and near the planes of maximum elevation and depression, the motion, for a certain distance, will be almost wholly horizontal, and then the vertical motion, having commenced, will only gradually increase, whilst, on the other hand, at the periods of approaching, passing, and leaving the sun's equatorial plane, the proportion of the vertical velocity to that of the horizontal must be considerably in excess of the general average which is (for the purpose of avoiding complexity) stated above.

For the same reason we have, thus far, treated the earth's orbit as a circle. When the relation of the vertical motion to the gravitative force, as the sustaining and controlling cause, has been more particularly considered, the ellipticity of the orbit will be taken into consideration.

(3) THE MECHANICAL RELATION OF THE PLANET'S VERTICAL MOTION TO THE GRAVITATIVE FORCE OF THE SUN.

Having given a general explanation of the theory, let us now consider with more particularity that vertical motion of the earth which, combining with the horizontal motion of the orbital revolution, converts the orbital path of the earth into an elliptic circle (the ecliptic) oblique to the equatorial plane of the sun.

In fig. 2, *S* represents the sun; and, *m. r. n.* the vertical motion of the earth through 47° ; the line *r. S.* representing the plane of the sun's equator.



Let us suppose, the earth being at its maximum elevation at *m*., that the vertical motion of ascent has ceased, and that the earth is proceeding in its orbit, for the moment, horizontally at that elevation. What are the conditions in respect to the gravitative influence of the sun? In the first place let us not forget the horizontal motion and the dynamical conditions belonging to that motion, because it follows that the body (the earth) is restrained and controlled by the centrifugal force to which it is subject as well as to the attractive force of the solar gravitation.

The attractive force of the sun acting in the direction

of the line *S. m.* is opposed by the centrifugal force belonging to the horizontal motion, but it is not wholly opposed thereby; for that force acts in a direction parallel to *r. S.* and at right angles to the line *n. r. m.*

By applying the rule for the resolution of forces, the oblique force *S. m.* is equivalent to a horizontal force *S. r.* acting towards the centre of the sun, opposed by the centrifugal force; and a vertical force *m. r.* unopposed, which is active in causing the earth to descend towards *r.* with a continually accelerated velocity.

The earth therefore descends, and in descending satisfies that part of the whole attractive force which acts vertically (and which is proportional to the whole as *r. n. : r. S.*) by approaching the sun, for the distance *r. S.* is less than the distance *m. S.* But as the earth approaches the horizontally plane *S. r.*, the proportion of the attractive force which acts vertically continually diminishes, and, when that plane is actually reached, the whole of the force is employed horizontally in counteracting the centrifugal force belonging to the orbital revolution.

The earth has now acquired a very considerable vertical momentum, and, passing the horizontal plane of the sun's equator, continues to descend with the velocity belonging to that momentum. That velocity begins to diminish almost immediately after the plane has been passed, but for the first few degrees of angular descent the diminution can scarcely be perceptible. As the angle increases there is, again, resolution of the whole attractive force into the horizontal and vertical; of which, the vertical portion now opposes the continued descent of the earth. This opposing force must evidently increase

as the angle increases, and must have for its effect an accelerated diminution in the velocity of the earth's descent; ending, when the angle has increased to $23\frac{1}{2}^\circ$ in the cessation of the earth's vertical motion downwards.

But the vertical force continues to operate, and no sooner has the earth's downward motion entirely ceased than an upward motion gradually commences. The conditions are now precisely similar to those which prevailed at the commencement of the descent, with the difference only that the direction of the motion and of the vertical force is inverted.

The ascent, therefore, continues until the horizontal plane is arrived at with accelerated velocity, which velocity then commences and continues to diminish until, at the $23\frac{1}{2}^\circ$ elevation above the plane, the upward motion of the earth is entirely overpowered by the attractive force and the descent again commences.

The revolving body (the earth) has thus a vertical motion of oscillation throughout the 47° contained between the points of maximum elevation and depression *m. n.*, whilst travelling through the circular orbital path of

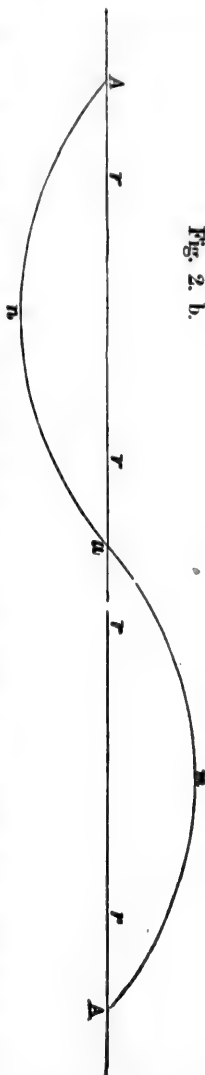


Fig. 2. b.

revolution. The oblique path of the body thence resulting may be, perhaps, more clearly understood by reference to the accompanying figure (fig. 2, *b.*) in which *r.r.r.r.* represents the outer edge of the horizontal orbital plane, and *A. m. a. n. A.*, the path of the revolving body, the circular (elliptical) figure having been separated at *A.* and extended into the figure contained between the (separated) points *A. A.*

(4) THE ELLIPTICITY AND DYNAMICAL ELEMENTS OF
THE ORBIT.

For a full and correct appreciation of the earth's (or other planet's) actual orbit, it is necessary to take into consideration the fact, ascertained by astronomical observation, that the orbit is not a perfect circle but an ellipse.

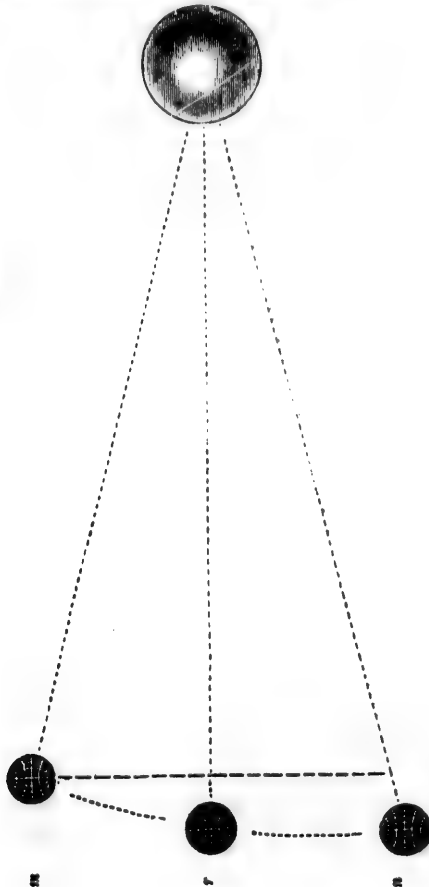
We have already remarked that, recognizing the vertical motion, although the planet's oblique orbit be an ellipse (*i.e.*, an ellipse posited obliquely), yet the horizontal section or plane through the centre of the ellipse might be a true circle. In the case of the earth, however, it is known that the horizontal plane of the orbit is also elliptical because the apparent increase and decrease in the size of the sun shows the earth to be nearer to the sun at the time of winter solstice than at any other part of the orbit.*

A distinct apprehension of the ellipticity of the orbit, as arising from the horizontal (*i.e.*, the centrifugal and

* We will reserve for the present some general considerations on the subject. See the last section. (12) The solar system, and the physical arrangements of the stellar universe.

centripetal) oscillation will enable the student to correctly understand the modification caused thereby in the compounded orbit. A vertical section of this is shown in fig. 3, which makes apparent the deflection from the simple vertical motion by composition with the horizontal oscillation... inwards when the earth is ascending and outwards when descending.

FIG. 3



To sum up, therefore, the dynamical elements of the orbit..... the oblique elliptical path of the earth is compounded of three motions. (1) The horizontal motion of orbital revolution around the central primary. (2) The centrifugal and centripetal motion of horizontal oscillation. (3) The vertical motion of ascent and descent perpendicular to the horizontal plane of the sun's equator. *i. e.*, the vertical oscillation.

In considering the ellipticity of the orbit as thus illustrated, the probability at once suggests itself that the elevation and depression of the earth (planet) at various parts of its orbit are proportional, or nearly so, to the horizontal distance of the earth (planet) from the sun; that is to say, the amount of maximum elevation for the one semi-orbit and the amount of maximum depression for the other, will be proportional to the comparative lengths of the horizontal radius-vector measured from the centre to each extremity of the major-diameter of the ellipse respectively; because the extent of the vertical oscillation being of the same nature as the horizontal, to which the ellipticity of the orbit (considered as a horizontal plane) is correctly attributable, it appears probable that the same impulse, whether imparted in the first instance or derived from some perturbing influence subsequently, which caused the one will have also caused the other; and hence that the arcs of vibration or the spaces through which the oscillating motions extend, in the two directions respectively, *viz.*, the vertical and the horizontal, will be proportional to each other.

The same conclusion will commend itself if the case be considered somewhat differently:—Let us suppose the ellipse, posited obliquely to the sun's equatorial plane, to have for its horizontal section by that plane a true circle,

and then let us suppose the sun to be situated eccentrically within that circle (*i.e.*, a little away from the true centre of the circle) we shall then have conditions coinciding with the existing conditions as observed astronomically, but it is also known that the extreme angular elevation of the sun's apparent path equals the extreme angular depression of that path, and therefore the supposition includes that of a vertical motion proportional to the length of the radius-vector, that is, so much less on that side of the orbit which is less distant from the sun.

A correction will, therefore, have to be made accordingly in our preceding estimate of the vertical distance, above and beneath the nodal plane, through which the earth's motion extends:

Taking the distance, at aphelion = 96,595,000 miles,
 and, at perihelion = 93,405,000 miles,
 then $37,255,000 + 625,500 = 37,880,500$ miles for the
 maximum depression,
 and $37,255,000 - 625,500 = 36,629,500$ miles for the
 maximum elevation.

It may be observed that the verticle motion of the earth in its orbit is very closely allied to the oscillation of a pendulum, the central place of the earth, when passing the plane of the sun's equator, corresponding to the central place of the pendulum in its oscillation when at the point nearest to the earth, and the attractive force of gravitation being, in both cases alike, the active agent in producing and limiting the effect.

Let us contrast with the foregoing exposition of the theory of the earth's perpendicular axis, that well known explanation of the same phenomena, which, for the sake of distinction, we will term the theory of the earth's inclined axis.

(5) THE THEORY OF THE EARTH'S INCLINED AXIS.

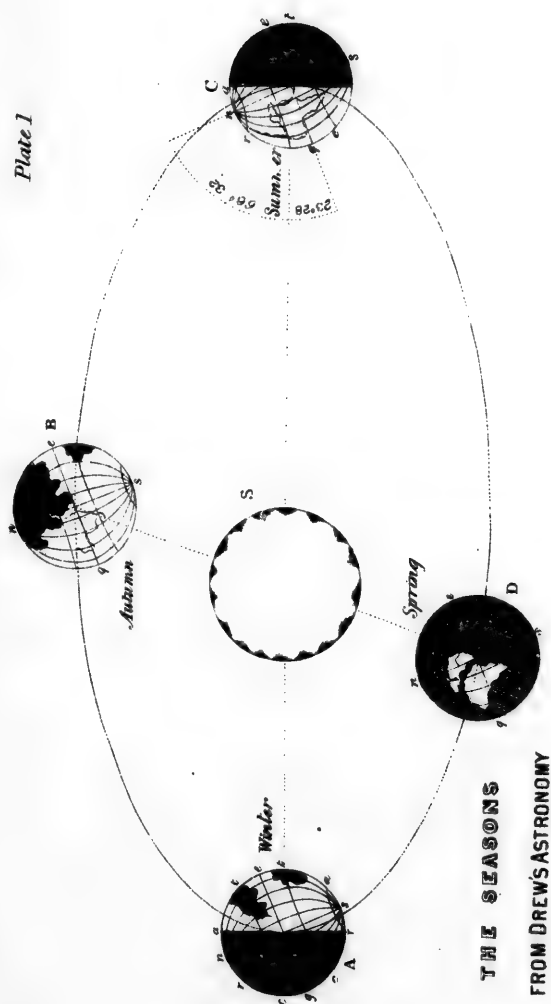
This theory teaches that the axis of the earth is inclined to the axis of the celestial sphere at an angle of about $23\frac{1}{2}^{\circ}$, and that the earth travels throughout the orbit retaining the same absolute position; or, as it is described in some astronomical works, "the earth's axis remains parallel to itself in all positions;" the meaning of which is defined by illustration to be that . . if the axis of the sun perpendicular to the ecliptic is supposed to be extended north and south, then . . at the summer solstice, the north pole of the earth inclines towards the perpendicular axis of the sun, and the south pole of the earth away from it: . . at the winter solstice, the south pole of the earth inclines towards the perpendicular solar axis, and the north pole of the earth away from it; . . and at the vernal and autumnal equinoxes, the polar axis of the earth is inclined at the same angle, in the direction of the earth's orbital path; in the one case the south pole being in advance, and in the other the north pole being in advance

Fig. 4. Plates 1 and 2 (The Seasons) . . illustrate the supposed position of the earth relatively to that of the sun in the four places of the orbital revolution, namely, the equinoxes and solstitial points.

To this theory the first objection that suggests itself is . . that by it the earth is assumed to travel in an orbit, which is confined strictly to an undeviating horizontal plane, and it is not shown how this is possible . . for, no restraining force is assigned; and, therefore, no cause is shown why the attractive force of other planets acting from above and below the horizontal plane do not produce vertical deviation.

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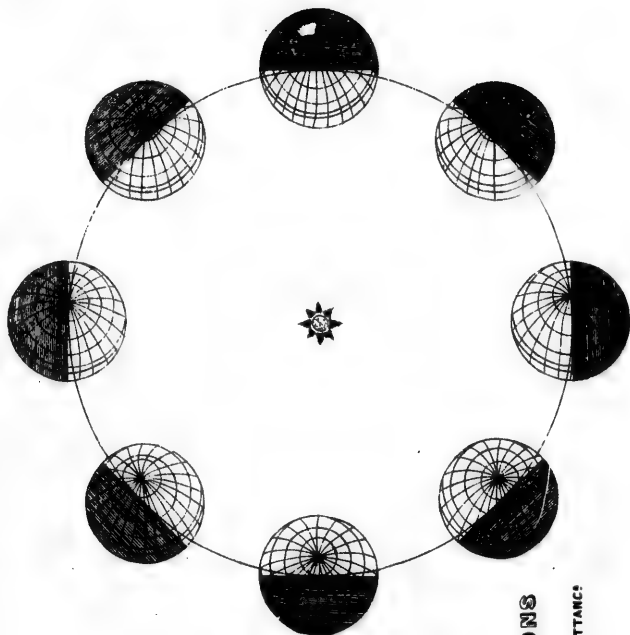
Plate 1



THE SEASONS

FROM DREW'S ASTRONOMY

Plate 2



THE SEASONS
FROM THE ENCYCLOPEDIA

NEW YORK: HENRY HOLT & CO.

But, on a close and particular comparison of this theory (of the inclined terrestrial axis) with the observed facts of astronomy, it becomes evident that the phenomena cannot be fully explained by, or reconciled with it. On the contrary, the practical astronomer who holds the theory is compelled by the facts to (virtually) attribute a vertical motion of ascent and descent to the earth; notwithstanding that such an admission is quite inconsistent with, and fatal to, the theory.

(6) THE TWO THEORIES CONTRASTED.

In order to make this clearly apparent we will now compare the two theories by considering each of them in its general relation to the celestial sphere...i.e., to the fixed stars generally, to the constellations of the Zodiac, to the apparent path of the sun amongst those constellations, and to the orbits of the planets considered relatively to the sun, and to each other.

(m.) *Illustration of the theory of the perpendicular terrestrial axis.*

In figure 20,* the earth E is supposed to be at *a*, near the winter solstice, and at *b*, near the summer solstice. Therefore, according to the theory of the perpendicular axis, (as already explained), the earth at *a* is at (about) its maximum elevation above the plane of the sun's equator, and at *b* is at its maximum depression below that plane. Assuming, then, the earth to be situated at the elevated place *a*, in the month of December, the apparent place of the sun, to a terrestrial observer, will be in the constellation at which a line drawn from the earth through the centre of the sun would, if produced,

* In copying this figure the east and west have been inverted.

eventually arrive. The apparent place of the sun at that time of the year is known to be in the constellation Sagittarius.

Now the theory called the Copernican System, according to which the earth and other planets revolve around the sun, is not only accepted by astronomers as a demonstrated theorem, but may be considered the general basis upon which modern astronomy is constructed; it is, therefore, the earth and not the sun which, in fact, changes its position from time to time relatively to the other members of the solar system, and relatively to the independent stellar systems (fixed stars.)

A question which at once proposes itself and invites a plain and intelligible reply is:—What, according to the perpendicular-axis theory, is the apparent place of the earth in the heavens, viewed from the sun in the month of December, when, to the terrestrial observer, the sun appears to be in the constellation Sagittarius? To this question there is no difficulty in replying that the earth's apparent place is at that time, as shown in Fig. 20, in the constellation Gemini.

Let us now suppose the earth to proceed in its orbital revolution through 180° . By the theory it will, having passed the solar equatorial plane, have descended to the point of its maximum depression beneath that plane, namely $23\frac{1}{2}^\circ$, equal to its elevation above the plane when occupying the place at *a*. The apparent relative places of the sun and earth will now have become interchanged. To the terrestrial observer, in the month of June, the sun appears to be in the constellation Gemini, and (assuming our theory) to the solar observer the earth at *b* must appear to be in Sagittarius,

consequently, therefore, according to the theory, the earth relatively to the equatorial plane of the sun actually describes in the heavens that (ascending and descending) oblique circle called the ecliptic, which necessarily cuts the solar equatorial plane in two places.*

Fig. 21 repeats the illustration which is amplified by the addition of a superior and an inferior planet. The angular vertical deviation in the case of the superior planet is here shown as less than that of the earth, but we shall give reasons for believing the extreme angular vertical deviation to be the same for all the planets belonging to the solar system. The neighbouring constellations above and beneath Sagittarius and Gemini are indicated for the purpose of illustrating the variation of obliquity in the apparent paths of the several planets which thus becomes readily and satisfactorily explained.

The celestial globe, as constructed at the present time, may be made to correctly represent and illustrate the 'theory of the perpendicular axis.' The North Polar axis of the celestial globe may be considered to practically include the Pole of the earth and also the Pole of the sun, because the polar axis of both are perpendicular and therefore parallel to each other, and the distance of 95 million miles between them is, in comparison with the great distance of the fixed stars from the sun, practically inappreciable.† The point marked on the globe "Pole of the Ecliptic" is

* But in the theory of the inclined-axis the solar equatorial plane is the ecliptic, and which cuts the equatorial plane of the earth in two places.

† On this point we are adopting for the moment the presently received teaching of astronomy, but there seems to us, at least, a probability that a very appreciable quantity of space between the polar zenith of the sun and that of the earth may be parallaxically perceptible and, perhaps, even enable an approximate measurement of the distance of the Pole-star from the sun to be obtained of a more reliable

the point intercepted by a straight line which passes through the centre of the oblique circle described by the earth in its ascending and descending orbital path, and which line is perpendicular to the plane of that compound circle. Since the plane of that circle is oblique to the solar equatorial plane and forms an angle therewith of $23\frac{1}{2}^{\circ}$, the point in the celestial sphere intercepted by that line is necessarily situated $23\frac{1}{2}^{\circ}$ from the pole of the sun, which last is also the pole of the celestial sphere as viewed from the sun, and is also the pole of the mean horizontal orbital plane (or nodal plane) of planetary revolution belonging to the Solar System, and may be, moreover, considered as practically* (because apparently) the pole of the earth, although, in fact, this last revolves around it at a distance of about 95 million miles in an character than any of the estimates hitherto made. When considered for the first time there may be some difficulty in understanding that the earth, having a particular star almost directly above its north pole, can travel to a distance of about 190,000,000 miles, that is—to the opposite extremity of its orbit—and yet still have the same star almost directly over its north pole as before; such, however, is the case, and when the comparatively enormous distance of the stars is taken into consideration, it is readily understood that the diameter of the earth's orbit, great as a distance of 190,000,000 miles appears to be in a merely terrestrial sense, is not sufficient to cause more than a very slight alteration in the angle at which the light from the star arrives at the eye of the observer. Plate 6, (Fig. 24) may serve to give an idea of the relation. The pole of the ecliptic, shown by the arrow crossing the stellar sphere, is the point intercepted by a central line at right angles to the plane of the compound oblique orbit of the earth and is at about $23\frac{1}{2}^{\circ}$ east of the pole of the celestial sphere. The actual relative distance of Polaris to that of the earth is supposed to be far greater than shown in the plate.

* See foot note to the preceding page. It has been previously explained that granting the perpendicular position of the earth's axis the polar zenith of the sun and that of the earth will appear to coincide, or very nearly so.

ellipse which is a counterpart of the earth's orbit around the sun.

Let us now consider in the same manner 'the theory of the inclined terrestrial axis' as set forth in works of astronomy. (Subject, however, to that correction, as to the definition of the celestial equator, stated and explained in the *Introductory Observations*.

(n) *Illustration of the theory of the inclined terrestrial axis.*

In fig. 22,* the illustration is similar to that of fig. 20, but adapted to the requirements of this theory. We have the earth at *a*, as before, in the month of December at about the time of winter solstice, when to the terrestrial observer the sun appears in the constellation Sagittarius; and in answer to the former question, as to the apparent place of the earth viewed from the sun, the reply is the same as before . . . in the constellation Gemini. When the earth has proceeded through the one half of its revolution to the place *b*, the apparent relative positions of sun and earth are, as before, interchanged, and the sun appears in Gemini, the earth in Sagittarius.

If this theory were the new, and that of the perpendicular axis the old one, the astronomical student on looking at this figure (fig. 22) would be apt at the first moment to say:—'This won't do at all, things are not in their right places.' A little consideration, however, will show that we now have a very complicated and difficult case to deal with, and it will soon become apparent that, if not in their right places, (which we are prepared to admit) they are where the theory of the inclined axis as now taught, if adopted, obliges us to put them.

* In copying the figure, the east and west, and, with them, the inclination of the earth's axis, have become inverted.

So long as we confine the consideration of the case simply to the sun, the earth, and those constellations which constitute the zodiac, the appearances to the terrestrial observer, which, without reference to their relative positions and dynamical relations in and as belonging to the celestial sphere, are the same as in the former case, will not show anything to be amiss. The earth, indeed, is now supposed to revolve in a horizontal plane uniformly coincident with the equatorial plane of the sun, the (pole of the ecliptic being a prolongation of the sun's polar axis) and both the constellations 'Gemini' and 'Sagittarius' are now on the same horizontal plane; but the earth's equator, to which the terrestrial observer refers to determine his relative position, and which becomes therefore the basis of his position, is now inclined at an angle of $23\frac{1}{2}^{\circ}$ to the equatorial solar plane—which now is also the orbital plane of the earth's revolution; consequently the apparent place of the sun (viewed from the earth at *a*) is at an angular distance of $23\frac{1}{2}^{\circ}$ beneath the plane of the terrestrial equator, and so also of the constellation Sagittarius, which appears at the same angular distance beneath that plane.

And again, when the earth has proceeded through the half revolution and arrived at the second station *b*, since the earth's axis, according to this theory, has uniformly the same inclination in the *same absolute* direction, or, as it is usually expressed in astronomical works, since the inclined axis of the earth 'remains parallel to itself' throughout the orbital revolution, the sun then has an apparent elevation of $23\frac{1}{2}^{\circ}$ above the terrestrial equatorial plane; and so likewise of the constellation Gemini which appears similarly elevated. With respect to the

constellations, it is evident by the figure that relatively to the earth's equator, Gemini will appear elevated and Sagittarius depressed in whatsoever part of its orbit the earth may be, because the earth's inclined axis remains uniformly 'parallel to itself' throughout the annual revolution.

But, what is the ecliptic, according to this theory? The ecliptic is the (imaginary, fictitious) path of the sun's apparent motion in the heavens, and is, also, the natural equator of the heavens (celestial sphere.) But, then, has the sun an actual motion? Certainly not. By the Copernican theorem the sun is the fixed centre of the solar system. But does not the earth's orbit deviate from the equatorial plane? Is it not sometimes stated that the orbital plane of the earth is inclined at some angle to the equatorial plane of the sun? According to the theory, no deviation in the earth's orbital plane from the sun's equator can take place, and any statements, if there be any, of such deviation are evidently inconsistent with the theory, for, according to the theory, the angle of obliquity of the earth's equator to that of the sun is $23\frac{1}{2}^{\circ}$, which inclination is retained uniformly. Now if the earth, retaining that inclination, were to deviate vertically above or below the horizontal plane of the solar equator, then would the apparent depression or elevation of the sun relatively to the earth's equatorial plane, exceed the limit of $23\frac{1}{2}^{\circ}$, which is well known to astronomers to be the maximum.

Therefore, according to this theory, the earth revolves around the sun in an uniformly horizontal plane coincident with the equatorial plane of the sun.

Let us now amplify the illustration as before by the addition of the superior and inferior planets. Fig. 23.

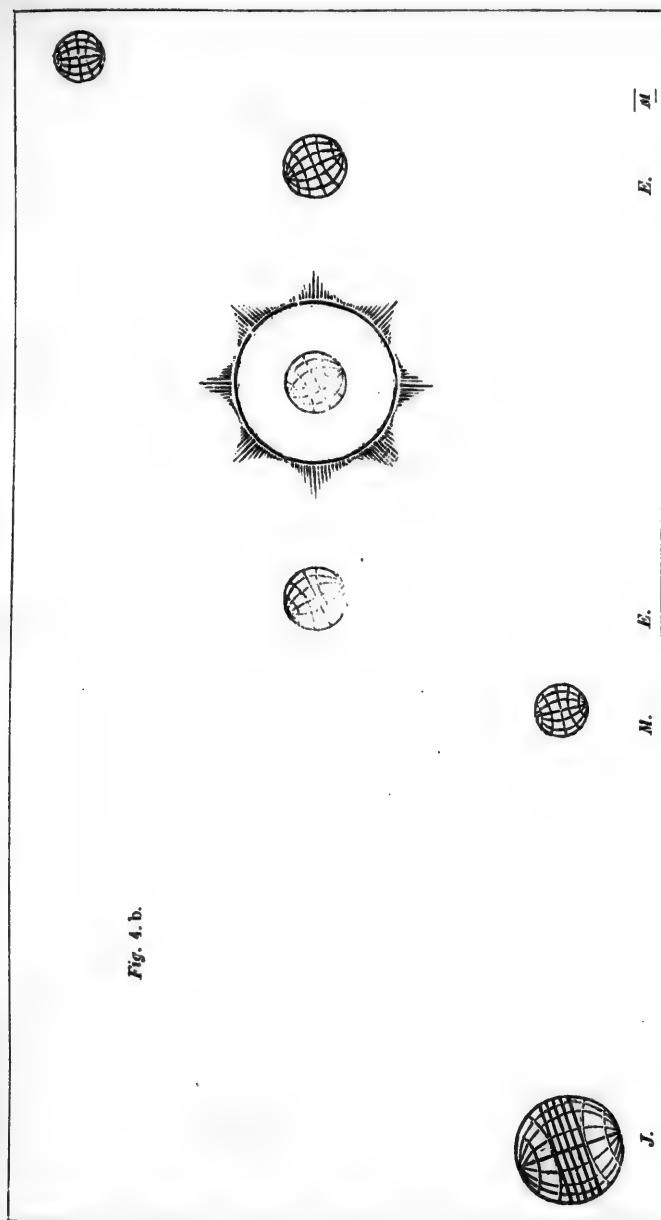
Here we are met by a difficulty which does not appear to be reconcilable with the recognized laws of gravitation. It is at once evident that each of the planets must have an orbital plane more or less oblique to that of the earth, for if the orbital plane of any one of the planets were coincident with that of the earth, then at each conjunction or opposition there would be either transit, occultation, or eclipse, as the case might be. Since, therefore, each of the planets has an orbital plane differing from that of the earth, a strong probability is suggested that each will have its own particular plane more or less oblique to each of the others.* But here is the difficulty. What is there to keep a planet from vertical deviation when the earth, (for example) situated in an orbital plane oblique to that of the planet's orbit, is attracting it upwards; or what prevents the earth from vertical deviation when a planet revolving in a less elevated plane is attracting it downwards?

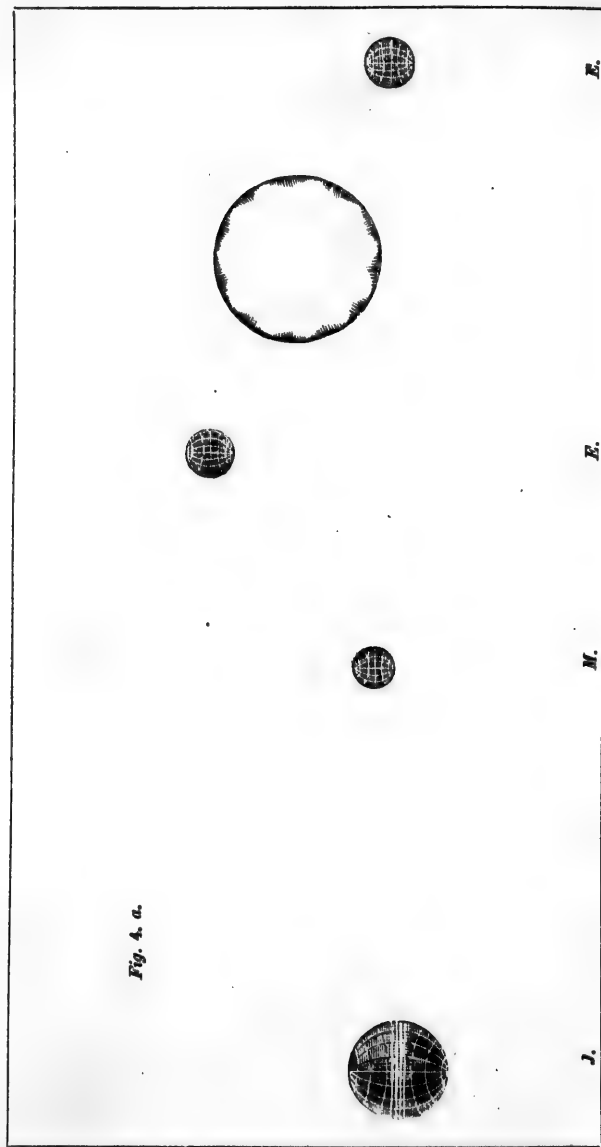
Having stated this difficulty, which, indeed, is, in our opinion, a difficulty (†) of so serious and insurmountable a character as to be in itself, independently, fatal to the

* It is not desirable to complicate the consideration of the subject by introducing in this place the case of a satellite, or otherwise the moon, subjected at the same time to solar and terrestrial gravitation from planes not coincident, would furnish a pertinent example. However, it seems to us, that in the extremely complex lunar theory, as now taught, a vertical deviation of the moon from the earth's equatorial plane is *virtually* admitted although not distinctly and directly recognized.

(†) The idea may suggest itself that, since the orbit of the planet is oblique to the solar equator, according to either of the theories, this difficulty must apply to both, if it apply to one of them; but examination will show that such is not the case, and will make more manifest the particular and fatal character of the difficulty in the case of the inclined-axis theory. Referring to fig. 4 b., representing the Earth, Mars, Jupiter and the Sun:—the line M.S.M., which, according to the inclined-axis theory, represents the

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theory of the inclined axis, we will now pass on to a more general consideration of the case.

Taking a celestial globe as at present constructed we find a point at an angular distance of $23\frac{1}{2}^{\circ}$ from the polar axis of the globe (*i. e.*, the fixed axis upon which the globe turns) marked 'pole of the ecliptic'—and we find the pole star (Polaris) close to that fixed axis of the globe. Is this construction consistent with the theory of the inclined terrestrial axis? Certainly, the polar axis of the earth being inclined at an angle of $23\frac{1}{2}^{\circ}$ to the polar axis of the celestial sphere, the equator of the earth is, by the theory, similarly inclined to the natural equator of the celestial sphere, and the apparent path of the sun, if it do not deviate from the equatorial plane of the celestial sphere, must be oblique to the circle of the earth's equatorial plane by the same angle. Now it is true the earth is not exactly in the centre of the celestial globe, which to an inhabitant of

undeviating plane of the orbit of Mars, is at an angle of about 40 degrees to the direction in which the attractive force of Jupiter is exerted; and to counteract this perturbing influence no cause is assigned, nor does it appear that there is any which can be reasonably so assigned, and if this deflecting force be supposed effective in occasioning deviation, in however small a degree, no cause whatever is shown why the planet should return to its former orbit.

Now in fig. 4 (*a*), which substitutes the theory of the perpendicular axis it becomes apparent that the effect of the perturbing influence which one planet exerts upon another with respect to the vertical motion is to slightly accelerate or retard the velocity, and, as a consequent to this effect, to slightly increase or decrease the magnitude of the vertical oscillation. Such effect would, of course, manifest itself as a slight variation in the apparent path of the sun. Since the general direction of the force and tendency of the effect is towards the nodal plane from both sides, the influence of each planet may be considered to assist, in some small degree, that of the sun in restraining and controlling the vertical motions of the other planets.

the solar system is theoretically occupied by the sun, but the distance between the sun and earth, as already stated, when considered in reference to the place of the pole in the heavens is scarcely appreciable. Polaris the terrestrial pole-star, which is very nearly the zenith of the earth's north pole, must be, therefore, according to this theory, always at an angular distance of about $23\frac{1}{2}^{\circ}$ from the pole of the celestial sphere.*

Let us now carefully compare the two theories as shown in the plates, Figs. 20 and 22;.....

Fig. 20, illustrating the theory of the perpendicular axis, Fig. 22, that of the inclined axis.

If the explanation of the two theories has been apprehended it will be evident that, supposing we can show 'Polaris' to be (practically) the pole-star of the sun as

* It seems, as stated in our introductory observations, quite usual at the present time to consider the earth as the centre of the celestial sphere and the equator of the celestial sphere to be an extension or projection of the earth's equator.

We have already objected to such doctrine as inadmissible, even if the present theory (of the inclined terrestrial axis) be upheld. The celestial sphere cannot be considered a merely statical abstraction, not a mere spherical chart of the heavens with the constellations mapped out upon it; the dynamical relations of those moving bodies which occupy the central part of it, and the doctrine which explains the relations and accounts for the relative motions of those bodies, also belong to the celestial sphere, and it must necessarily harmonize with them if it be ideally real and true. It may be proper here to remark that some astronomers express a misgiving that the polar axis of the sun is also out of the perpendicular. Let the reader ask himself these two questions..... Is not the sun to us, as inhabitants of the solar system, the natural centre of the celestial sphere? And is not the polar axis of the sun, to us, the *astronomical standard of perpendicularity*?

well as of the earth, the theory of the inclined axis becomes untenable.

Now, taking fig. 20, . . . (Theory of the perpendicular axis.) If from the centre of the earth at (*a*), its place of greatest elevation, we suppose a line drawn to the centre of the sun, that line will form with the extended polar axis of the sun an angle less by $23\frac{1}{2}$ degrees than a right angle (*i. e.*, an angle of $66\frac{1}{2}$ deg.): again, if from the centre of the earth at its place of mean elevation, in the plane of the sun's equator, we suppose a line to join the centre of the sun, that line will be at right angles to the axis of the sun (*i. e.*, at an angle of 90 deg.): and, again, if from the centre of the earth in its place of maximum depression, we suppose a line drawn from the centre of the sun, that line will form an angle greater by $23\frac{1}{2}$ degrees than a right angle. (*i. e.*, an angle of $113\frac{1}{2}$ deg.)

Taking fig. 22, . . . (Theory of the inclined axis.) Since, by this theory, the centres of the earth and sun are always in the same plane, or, in other words, the centre of the earth is always in the equatorial plane of the sun, a line drawn from the centre of the earth to the centre of the sun must always form a right angle with the axis of the sun in whatever place in its orbit the earth may be. Here, then, is a very distinctive difference in the requirements of the two theories; let us see whether this difference can be made available to determine which of them is in harmony with the known facts of astronomy.

In fig. 20, at (*a*) 'Polaris' (the pole-star of the earth) coincides with the polar-zenith of the sun (or north pole of the celestial sphere), and in fig. 22, in the corre-

sponding place of the earth, *Polaris* is $23\frac{1}{2}$ deg. west of the sun's polar-zenith.*

When the earth has removed to the opposite extremity (or to any other part) of its orbit, the same relative positions of the solar and terrestrial polar-zeniths still obtain in each of the two cases. But now let us, in Fig. 22, suppose a station on the earth $23\frac{1}{2}$ deg. from the north pole, and at such longitude that when the sun crosses the meridian of that station, the earth being at the western extremity of its orbit, the zenith place thereof coincides with the sun's polar-zenith (pole of the ecliptic) $23\frac{1}{2}^\circ$ east of '*Polaris*.' When the earth has removed to the eastern extremity of its orbit, exactly opposite its former place relatively to the sun, and the sun again crosses the meridian of the station, that station has for its zenith place a point $23\frac{1}{2}^\circ$ west of '*Polaris*' and 47° west of the (supposed) polar-zenith of the sun. Let this circumstance, as one of the requirements of the theory of the inclined terrestrial axis, be carefully noted.†

By this theory, however, the sun's polar zenith (pole of the ecliptic) is always at the same angular distance, on the same side of '*Polaris*.' But if this circumstance of the theory be upheld, the apparent rising and descending of the sun's path in the heavens during the earth's

* For the sake of simplifying the argument '*Polaris*' is here taken to represent the actual polar-zenith of the earth—from which it is $1^\circ 24'$ distant.

† The inexperienced reader may be cautioned that the effects of the earth's diurnal rotation are apt to suggest themselves in this connexion as consequents of the earth's orbital revolution. The comparatively simple case of the 'earth's rotation relatively to the poles of the ecliptic' will be found illustrated in the Appendix, which see.

NOTE.—Our figure (fig. 22,) having become inverted, *Polaris* is shown to the east instead of to the west.

orbital revolution, now asserted as a fact of observation by all observers, cannot be a true report, and must be rejected as a misrepresentation of the apparent phenomena, for, evidently, by the theory, the earth's orbital revolution must be in the same plane as that of the sun's apparent path; and, if the earth's path be projected upon the celestial sphere, the circle so obtained will coincide with the circle of the sun's apparent path (*i. e.*, the circle of the ecliptic) and, consequently, there can be no apparent rising and descending of the sun's apparent path manifested to the observer, because the apparent path of the sun will] be always in that same circle.

The equator of the earth will be, certainly, according to the theory, inclined at an angle of $23\frac{1}{2}$ deg. to the equator of the sun. and, therefore, the equatorial plane of the earth is, by the teaching of this theory, inclined at that angle to the equatorial plane of the sun; but, let the student particularly observe that this is quite another matter from supposing the earth's orbital plane of revolution (*i. e.*, the earth's apparent path as seen from the sun) to be oblique to the sun's equatorial plane, which by this theory of the inclined axis it is not. So that, if the theory be supported by the facts, it must be at all times evident from inspection of the heavens that the position of the equator of the earth is oblique, and that the circle in the heavens, formed by the extension (or projection) of the earth's equatorial plane, is simply a circle in the celestial sphere oblique to the circle of the plane of the earth's orbital revolution, which latter is also the circle of the sun's apparent path. It therefore becomes evident that the known facts of observation—namely, that the sun does not appear to remain constantly

in the circle (plane) of the earth's orbital revolution, but appears at one time of the year to ascend above, and at another time of the year to descend below that circle—are inconsistent with the theory of the inclined axis.

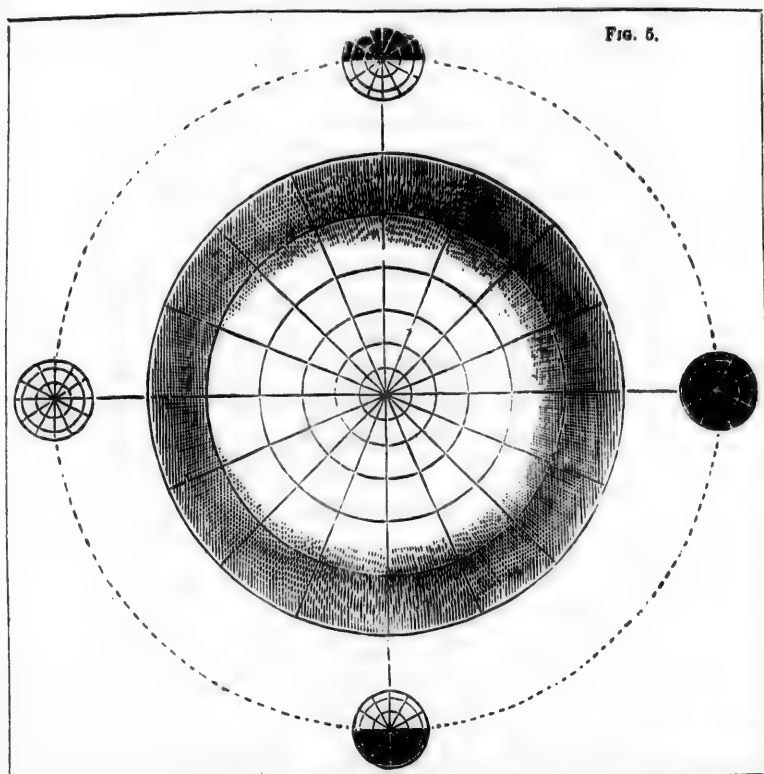
This fatal objection to the theory has been kept from manifesting itself by confounding two entirely distinct circles, circles which are inclined to each other at an angle of $23\frac{1}{2}$ deg., under the same name—viz., both have been called and are known as the 'equinoctial circle.' Now that circle in the heavens, which is oblique to the ecliptic and cuts the ecliptic in two places, is, by the teaching of the theory, simply the circle of the earth's equatorial plane extended to the celestial sphere,* but explanation of the facts of astronomy requires recognition that the earth's plane of revolution ascends on one side of the orbit and descends on the opposite side, relatively to the sun, and it is evident that the projection of this orbital path on the celestial sphere (*i. e.*, the apparent path of the earth as seen from the sun) must describe a circle oblique to the sun's equatorial plane. Therefore, by teaching that this circle (of the earth's orbital path) is identical with the circle of the earth's equatorial plane, and by giving to both the same name of the equinoctial circle, the difficulty is apparently got

* The earth's equatorial plane (by the perpendicular-axis theory) is always parallel to the plane of the equinoctial, but coincides with that plane only at the times of the nodes. The equinoctial (by that theory) is, therefore, strictly speaking, the mean plane of the earth's equator which retaining always the same horizontal position, moves from one extremity of the orbit to the opposite. This movement of 190 millions miles horizontally and 75 million miles vertically is not supposed to have a sufficient parallax effect on the distant stars to make itself directly perceptible as a movement of position when projected on the celestial sphere.

over, but, when examined, it becomes evident that such teaching is inconsistent and directly at variance with the theory of the inclined terrestrial axis, which requires the plane of the earth's orbital revolution to coincide with the equatorial plane of the sun. The effect of this practical teaching is to thus constantly rectify the theoretical position of earth and sun, by the apparent and actual position of the sun in the celestial sphere. The practical teaching takes the celestial sphere and turns it upon the sun (so to speak), as a central (axial) point, out of the position ascribed to it by the theory into the position required by the facts of observation. It appears, moreover, that the practical astronomer is constrained by the evidence of the phenomena to recognize an actual ascent and descent of the earth. Hence, in astronomical treatises such expressions as:—'Obliquity of the earth's orbit,' 'the ascending and descending nodes,' 'the inclination of the earth's orbit to the ecliptic,' &c., &c. Now either of these expressions is quite inconsistent with the theory of the inclined terrestrial axis. To be convinced that it is so, it will suffice to refer again to fig 22, illustrating that theory, by which it will appear that the equatorial plane of the earth is oblique to the plane of the ecliptic, but that the plane of the earth's orbit coincides with the plane of the ecliptic, and that no deviation whatever of the orbit from that plane is admitted by the theory. Consequently such expressions as obliquity of the earth's orbit cannot be made use of consistently with the theory of the inclined axis.

In Figs. 5 and 6, . . . by greatly reducing the distance and bringing the earth very near to the sun. . . We endeavour to illustrate the relations of position and motion peculiar

to each of the two theories in such a way as may enable the reader to appreciate with distinctness their comparative worth as faithful interpreters of the actual facts.



THEORY OF THE PERPENDICULAR AXIS.

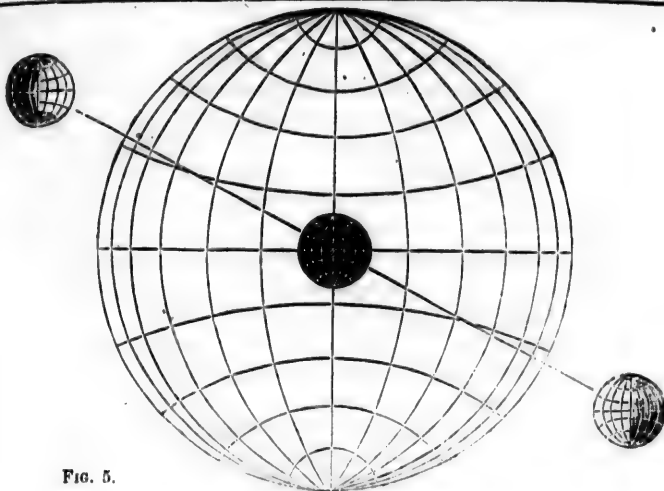


FIG. 5.

THEORY OF THE PERPENDICULAR AXIS.

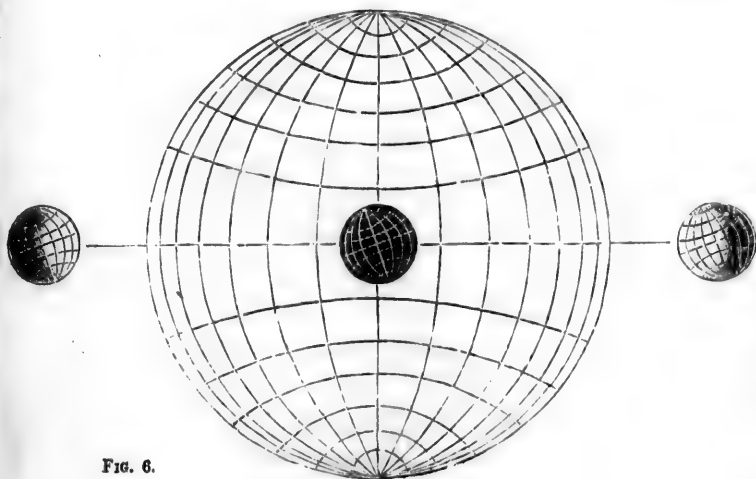


FIG. 6.

THEORY OF THE INCLINED AXIS.

NOTE.—The distinction between the *ecliptic* of the inclined-axis theory and the *ecliptic* of the perpendicular axis theory may be thus briefly stated: *The ecliptic of the inclined-axis theory*, fig. 22 is..the apparent path of the sun seen from the earth, and the apparent path of the earth seen from the sun; its plane is the plane of the earth's orbit; it coincides with the equatorial plane of the celestial sphere, and with the equatorial plane of the sun; it is *oblique* to the equatorial plane of the earth. *The ecliptic of the perpendicular axis theory*, fig. 20, is --- the apparent path of the sun seen from the earth, and the apparent path of the earth seen from the sun; its plane is the compound oblique plane of the earth's orbit; (being described by the earth's orbital ascent and descent from a lower to a higher and from a higher to a lower plane), it is *oblique* to the equatorial plane of the celestial sphere, and to the equatorial plane of the sun; it is, also, oblique to the equatorial plane of the earth; but, be it particularly noted that, by this theory, the earth's equatorial plane ascends above and descends below that of the sun, with which at the mean elevation it coincides; whilst, in the former theory (of the inclined axis) the equatorial plane of the earth is always parallel to the plane of the *equinoctial circle*, and coincides with that plane at the times of the nodes.

(7.) TRANSITS OF VENUS AND MERCURY.

An illustration and means of examining the merits of these two theories is afforded by the transits of Venus and Mercury. The theory of the oblique axis does not make the case of the earth's position and orbital revolution exceptional. The case of the earth is the case of each of the planets. The amount of the obliquity of the planetary equator, compared with that of the sun, may be greater in some planets and less in others. The axis may be more or less inclined relatively to the solar axis in each case; but the planet must not, by the theory, deviate vertically either above or below its own *ecliptic* or orbital plane, which has its particular angle of ob-

liquity to the plane of the earth's *ecliptic*, or, in other words, to the equatorial plane of the celestial sphere terrestrially considered.*

To examine the manner in which a transit of one of the inferior planets across the sun's disk may be made the means of practically ascertaining by observation which of these theories is sound and true, we will, in the first place, again refer the reader to figs. 21 and 23, illustrating the two theories respectively. By fig. 23 (theory of the inclined axis), since the orbit of the earth coincides, according to this theory, with the equatorial plane of the sun, the orbits of the other planets are simple planes, passing through the centre of the sun, all of which are oblique to the sun's equatorial plane and each of which is oblique to each of the others. But taking fig. 21, (theory of the perpendicular axis), although the plane of each planet is now compound, that is, compounded of two motions, the horizontal and vertical, yet the apparent relative movements and positions of the planets seen from the earth, under the conditions supposed by the one

* Herein we have another notable distinction between the two theories. By the old theory of the inclined axis, the inhabitants of each planet must have their own arbitrary position for the celestial sphere and the axis of the sun, adjusted to the particular inclination of the axis of their own planet. But, in the theory of the perpendicular axis, the equatorial plane of the sun is the mean plane of orbital revolution for (*the solar system*) each and all the planets, and the ecliptic, or apparent path of the sun, must, in each case, coincide with the orbit of that particular planet, and which orbit is more or less oblique to that of each of the other planets. The position of the celestial sphere and that of the sun's axis is, therefore, the same for each and all the planets. The celestial sphere is no longer in a general sense, an artificial and supposititious abstraction peculiar to one planet, but becomes natural, necessary, and definite, representing the actual position of all the members of the solar system relatively to the stellar universe. See *The Introductory Observations*.

theory, would not necessarily differ from their apparent movements and relative positions seen under the conditions of the other theory, supposing the earth's orbit in neither case to deviate from the equatorial plane of the sun. But by the theory of the perpendicular axis (fig. 21,) the earth's orbit does so deviate above and below that plane. Whereas, therefore, in the one case (fig. 23,) the transit is viewed from an invariable plane at a constant elevation, in the other, fig. 21, it is viewed from a variable plane of which the elevation is continually undergoing alteration.

To show this more particularly, we now refer to fig. 25, in which the transit of Venus is illustrated.

Transits of the planet Venus in relation to the perpendicular axis theory.

It is well known that the transits of the planet Venus take place sometimes in the month of June and sometimes in the month of December. Now, by the theory of the perpendicular axis, the earth in the month of December is at its maximum elevation above the solar equatorial plane, and in the month of June is at its maximum depression below that plane; whilst, by the theory of the inclined axis, the earth is constantly, at all times, in that plane. Consequently, according to the one theory, the terrestrial astronomer observes the phenomena from a plane much above or much below the sun's equator, and according to the other theory, he observes it always from a plane on a level with the sun's equator. If, therefore, the planet cross the sun's disk exactly at the time of its node, it would be seen, according to the inclined axis theory, to pass across over the sun's equator, whether the month were June, December or any other month;

but, according to the perpendicular axis theory, if seen in June (*i. e.*, from below,) the apparent path of the planet would be considerably above the sun's equator, and, if seen in December (*i. e.*, from above) the path would be considerably below the sun's equator. Now it is true that if the planet has not quite reached or is somewhat past its node, when the transit takes place, its path, according to the inclined axis theory, would also appear to be above or beneath the sun's equator, according to whether the node were the ascending or descending node; but, evidently, for any specific distance of the planet from its node, the apparent place of the planet (shadow) on the sun's disc must be so much affected by the vertical motion of the earth as to afford a means of demonstrating the reality and quantity of that motion.

(S) PRACTICAL APPLICATION OF THE PERPENDICULAR
AXIS THEORY TO THE MEASUREMENT OF THE
SUN'S DISTANCE.

Assuming that the necessity has been now sufficiently demonstrated for acceptance of the theory of 'the perpendicular axis,' in place of the theory of 'the oblique axis,' we have to suggest that the vertical motion of the earth, being distinctly recognized, may be taken advantage of as an additional, and in some respects very advantageous means of measuring the sun's distance, which we will here endeavour briefly to indicate.

(See Fig. 27.)

Let us suppose the earth to be descending from the higher to the lower plane of its orbital revolution, and to have nearly reached the mean plane coincident with the equatorial plane of the sun (or, in astronomical phraseology,

to have almost reached its descending node.) A station being chosen on the earth in high latitude north, and the vertical distance of the station from the plane of the equator being determined (say 3000 miles) let the moment of the earth's equator (*a*) passing through the equatorial plane of the sun be noted, and, as the descent of the earth continues, let the moment when the northern station (*b*) passes the sun's equatorial plane be also noted. The value in time of the earth's vertical descent through a definite angular space will be thus obtained. Now the whole time occupied in the descent through the angular distance of 47 deg. (or $23\frac{1}{2}$ deg.) is known, and, therefore, since the metrical value of the base of the triangle is thus obtained, the distance of the sun becomes also known.* The correctness of the results, however, will be dependent on the uniformity of the angular velocity of the earth in descending, or, if it be not uniform, in a perfect knowledge as to the relative velocity in each section of its descent. Now we do not suppose that velocity to be uniform; it is, we apprehend, necessarily greater near the nodal plane of revolution, the place of least distance from the sun, when the momentum will be most effective on the vertical motion. But it is to be expected that the ratio of the velocity, in one part of the descent, to the average velocity or to the velocity in any other part, can be determined with accuracy.

* Of course, by taking a station similarly situated in the southern hemisphere, the ascent of the earth may be equally well utilized for the same purpose. It is submitted that from the enormous scale of the base line, of which a part thus admits of direct measurement, and from the facility with which the first observations can be frequently checked, a great degree of accuracy may be anticipated as an eventual result from this method of measuring the sun's distance.

The following illustration may serve to make the conditions of the case and the practicability of the method itself more distinctly understood :

Let the descent of the earth from *b.* to *c.* be found to occupy $10\frac{1}{2}$ minutes, then. * . . .

$10\frac{1}{2}$ minutes : 3000 miles :: 1 day : 411,428 miles

:: 91 days (3 months) : 37,440,000 miles.

Because $23\frac{1}{2}^\circ$ is a part of the circumference of the circle † of which the sun's distance is the radius,

$$\frac{180}{23\frac{1}{2} \times 3} = \text{ratio of radius in degrees.} = \frac{7.66}{3}$$

And $37,440,000 \times \frac{7.66}{3} = 95,000,000$ miles,

the required distance of the sun.

NOTE.—We have in the foregoing illustration of this method, to avoid complexity, taken only a supposed distance of 3,000 miles as the measured sine of the angle, but, on consideration, it will be evident that by providing a station in the southern hemisphere, similarly situated to that in the northern (i. e., in the corresponding lat. and long.), 6,000 miles of the earth's diametrical length may be made available for direct measurement with practical advantage.

To fully utilize this method, however, telegraphic com-

* On this assumption, the earth's vertical velocity of 286 miles a minute, —not quite 5 miles a second, is about one fourth the horizontal velocity of the earth's orbital motion. But we have here taken the average vertical velocity for the purpose of simplifying the illustration; as stated above, we suppose the vertical velocity when passing the nodal plane to be considerably greater than when the earth is near the commencement or termination of its descent (or ascent).

† $23\frac{1}{2}^\circ$ is the angular value of the earth's descent from the point of maximum elevation to the nodal plane.

munication between the stations by electricity would be necessary. Fig. 27, *R*, will serve to illustrate this extension of the proposed application before described. The first observation (in the earth's descent) is to be taken simultaneously at the three stations *d. a. b.* as soon as the station *d.* in the southern hemisphere arrives at the equatorial plane of the sun. The second three-fold observation to be taken when the station *a.* arrives at the same nodal plane; and the third three-fold observation when the station *b.* arrives at the plane. Since the observations above and below the plane at equal distances therefrom would be equivalent in respect to the visual angle, any slight error in the observation on the one side might be detected and rectified by means of the similar corresponding observation on the other side of the nodal plane.

(9) PARALLAX OF THE STARS.

The perpendicular-axis theory may be applied to obtain or facilitate parallax observations of the stars.

As to the facilities afforded by the perpendicular axis theory through recognition of the vertical motion of the earth in obtaining parallax of many of the stars, it may seem unnecessary to do more than call attention to the circumstance; we would observe, however, that the non-recognition hitherto of the earth's vertical motion must have much interfered with, and oftentimes rendered unsuccessful, the endeavours to obtain parallax by means of the orbital revolution of the earth (*i. e.*, helio-centric parallax) and it has, probably, had much to do in confirming, if not in originating, the supposition of the aberration of light. When distinctly recognized, precaution can, of course, be taken to prevent the parallactic influence of the vertical motion from compounding with

and confusing the parallactic effect of the horizontal orbital motion, and *vice versa*. Fig. 24,* illustrates the compound parallactic effect, when the earth from its place (E. 1) of maximum elevation at the western extremity descends to the lowest plane at the eastern extremity of its orbit, the star which is actually located at *a*. appears to move from *b*. where it is seen from E. 1., to *c*., where it is seen from E. 2.

But it should be particularly noted that perceptible parallax of distant stars by direct observation is altogether dependent upon the presence of stars still more distant with which to compare them. Even in those cases where the presence of stars at a much greater distance renders the parallactic effect perceptible ; it is not the absolute parallax of the nearest stars which is obtained but that absolute parallax minus the parallax of the more distant star. We say this fact is especially noteworthy, because in astronomical works of high standing it appears to be practically overlooked. The celestial sphere, instead of an Ideal limitation of space—i. e., a finite spherical space of vast extent, of which our solar system occupies the centre,—very useful to the theoretical astronomer as an abstraction, appears to have become considered a concrete existence, forming a sort of screen behind even the most distant stars, upon which they are supposed to be perspectively projected. † It is stated that attempts

* In this illustration the east and west of the figure have been inverted.

† It is true that in respect to the visual angle they may be considered as projected upon the firmament ; but what we wish to call attention to, as having been, apparently, in some measure overlooked, is that this parallactic effect is quite general to a large section of the heavens at one time, and applies to all the stars, in that section, according to their distances. If therefore, certain stars be chosen and considered motionless as a basis of

have been made quite without success, to obtain parallax of those distant stars. Sir John Herschel calculates what the distance of a star would be if a parallax of 1" were perceptible, and concludes that the distance is much greater because not even a fraction of 1" can be obtained; but it is by no means clear, supposing an absolute parallax of 1' or even more, instead of 1" for some of the stars be obtainable, that adequate and available methods have been adapted for rendering it perceptible. Should parallax of the more distant stars be obtained, that angular quantity, however much or little it might be, would be an addition to the parallax of the nearer stars, in those cases where parallax has been already obtained.

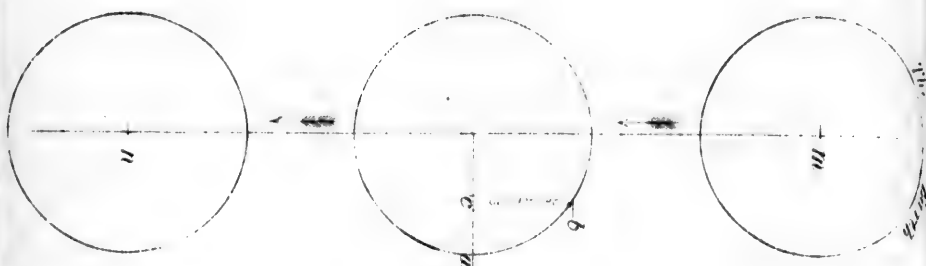
These observations apply to direct parallactic observations based upon relative position of one star to that of others; there is, however, another method (described under the head of parallax in Part Third) which may be termed trigonometrical parallax, and which is not subject to the same objection. It appears (theoretically) quite practicable by that method to obtain the absolute parallax of stars at almost any conceivable distance; but here again it may be observed that an attempt to put even this method in practice without a previous recognition of the earth's vertical motion would probably fail altogether, or end in a doubtful result, such that the inference drawn from one set of observations would be contradicted by the result of another set. Recognition

measurement to ascertain any parallactic displacement it is equivalent to ignoring parallax for all stars no less distant than those; because the stars supposed to be motionless being themselves subject to parallax, no effect would be perceptible.

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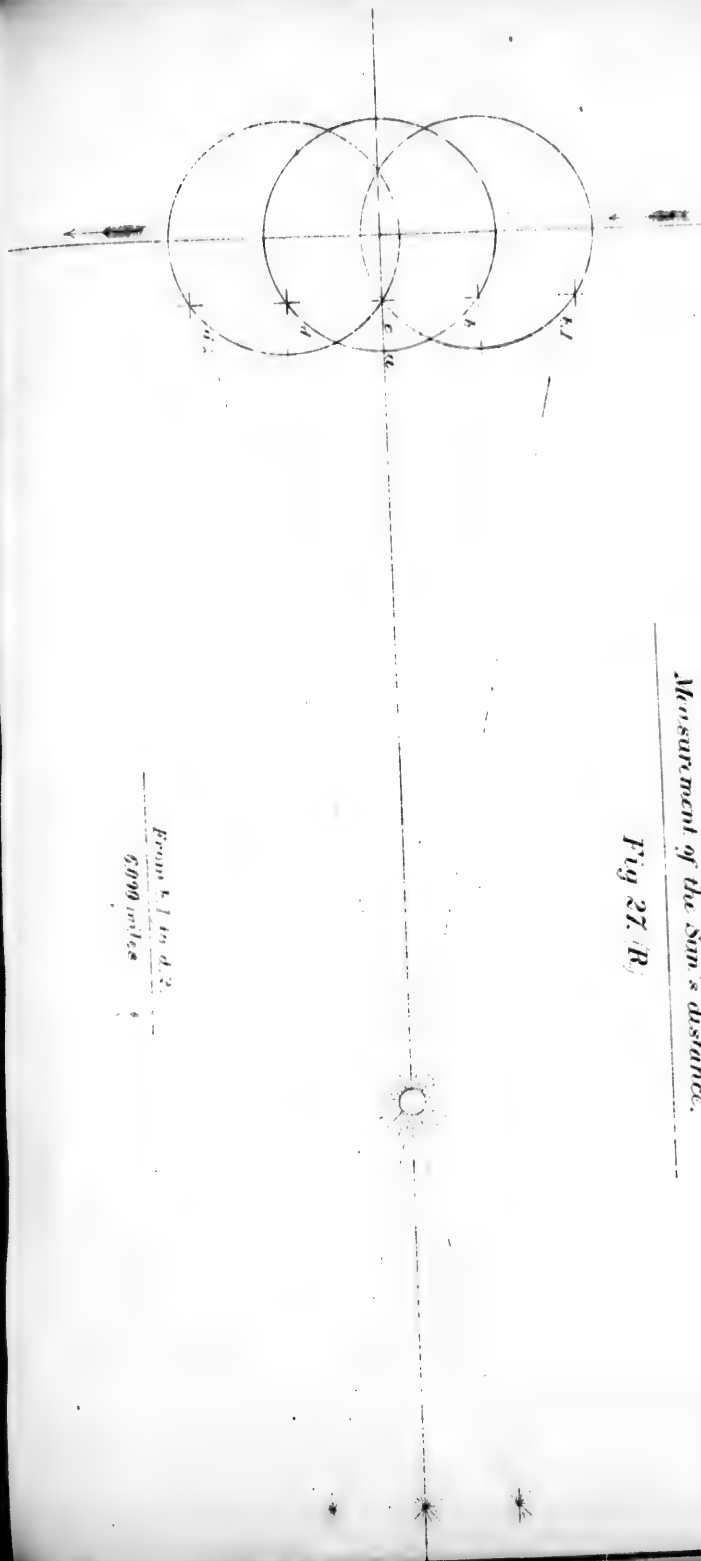
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Measurement of the Sun's distance
by Time and Trigonometry
Fig. 27

Measurement of the Sun's distance.

Fig 27. (R)



From E. J. to d. 2.
6000 miles

Transit of Venus.

fig 25



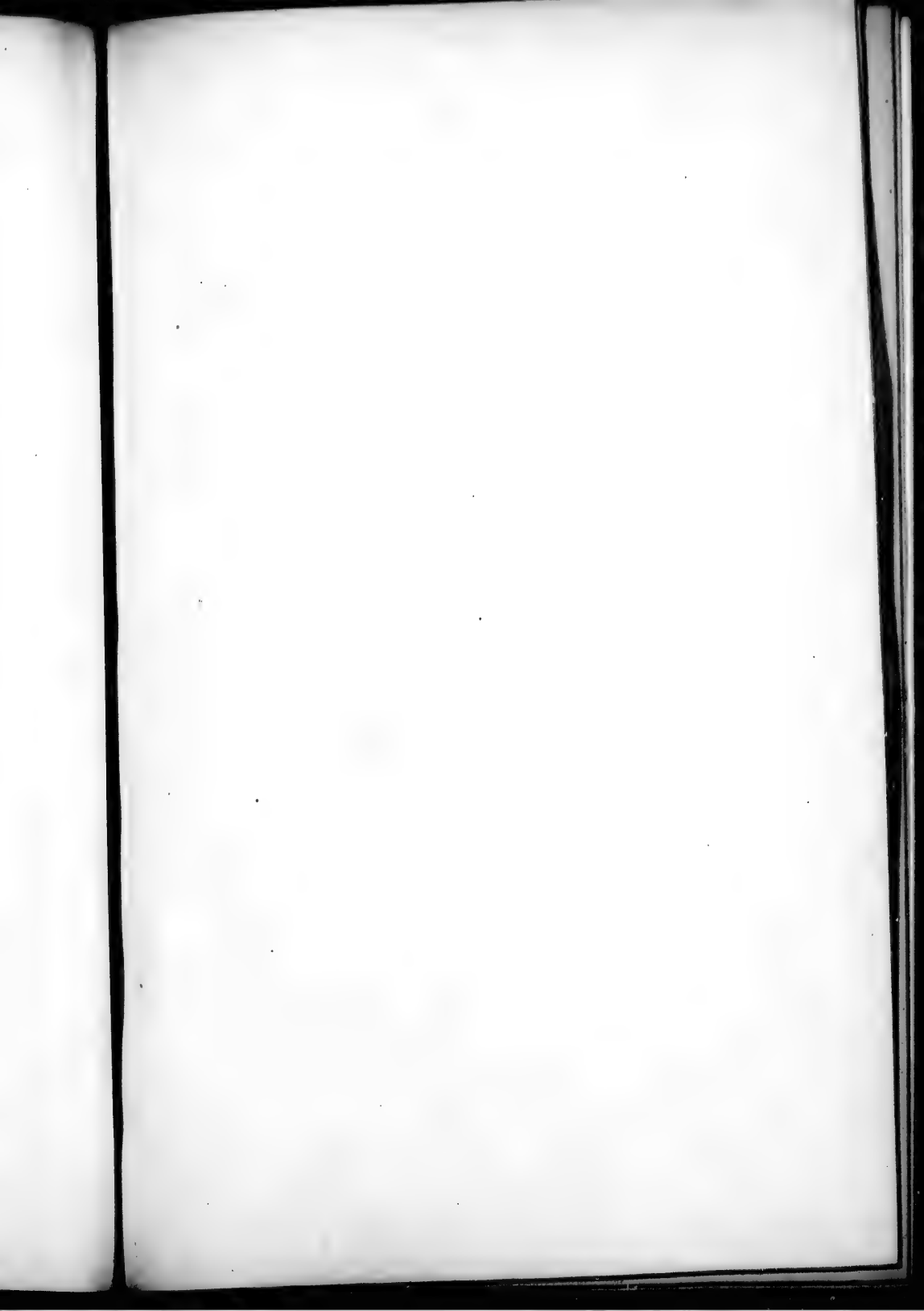
- a The Earth in December
- b The Earth in June
- c The Earth in June

by theory of perpendicular axis.
by theory of inclined axis.
by theory of perpendicular axis.

c

b

a



Transit of Venus.

Fig. 26

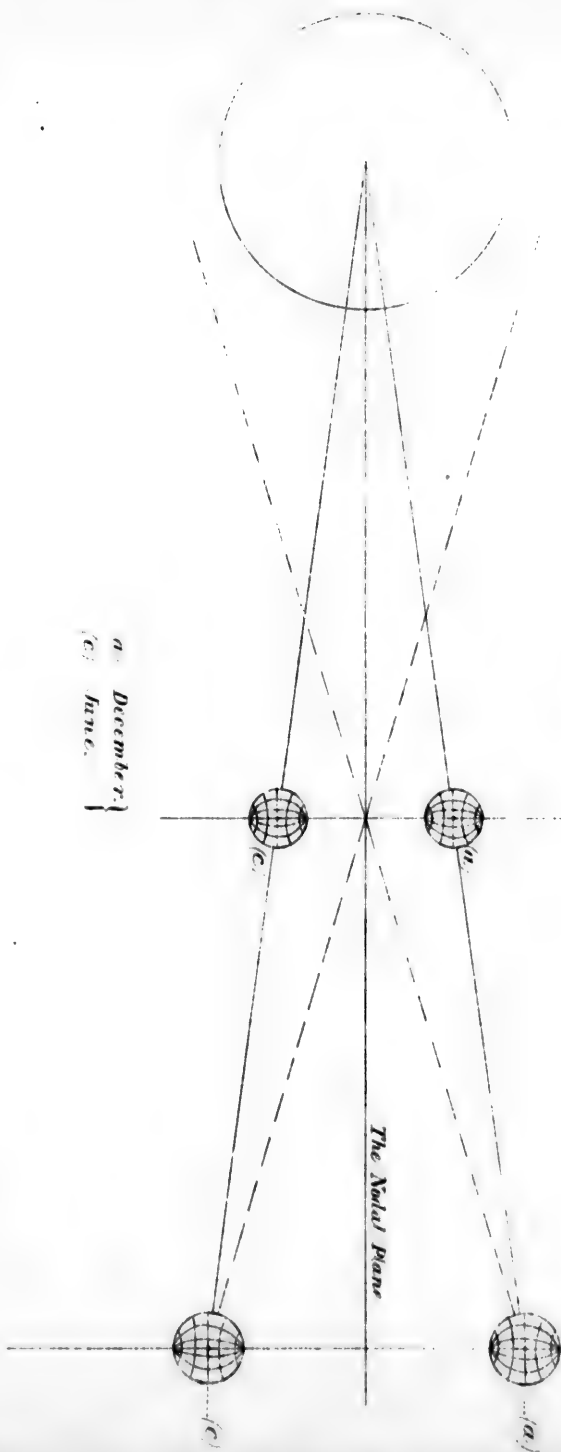


Fig. 24. Parallax.



of the earth's vertical motion makes apparent that such observations should be made at about the times of the nodes, when the earth's equator is passing through the equatorial plane of the sun, or, perhaps preferably, at one of the solstices when the earth being at its extreme elevation or depression is moving horizontally.

Referring again to fig. 25, illustrating the application of the perpendicular axis theory to the case of the planet Venus transitting the sun, we will now state more fully, in connection with the illustration referred to, the general doctrine of planetary revolution which belongs to that theory.

(10) THE GENERAL DOCTRINE OF THE COMPOUND OBLIQUE ORBIT.

From the manner in which, as explained and illustrated (page 21 *et seq.*), the mechanical relation of force and motion requires us to apprehend that the attractive force of the sun must control, regulate, and limit the vertical motion of the earth or other planet, it follows that,* unless there be some extraordinary interfering and perturbing cause, the amount of vertical deviation from the horizontal orbit must be in each planet directly proportional to the distance of that planet from the sun, being greater at the greater distance, less at the lesser distance. This statement is evidently equivalent to affirming that the angular vertical motion of all the planets is equal . . . i.e., that the vertical motion of each is similar in angular extent to that of each of the others.

* The reasons why we hold that the conclusion here stated must follow as a reasonable corollary will be presently considered with particularity.

The transit of Venus illustrates the generalization.

The practical application of this generalization to the particular case may be most readily explained by assuming (for the purpose of illustration) the distance of the planet Venus from the sun to be exactly one-half the distance of the earth from the sun. . . . the maximum elevation and depression of the planet, above and below the mean (nodal) plane common to both of them, would then be one-half the similar deviations of the earth. So that, if, at the time of Venus crossing the vertical plane joining the sun and earth, both the earth and the planet were at their maximum elevation, the apparent place of Venus would be, to the terrestrial observer, projected upon the sun's equator; and so, likewise, if both were at their maximum depression beneath the mean plane of orbital revolution, the effect would be the same. But if the planet, when crossing the vertical plane of junction between the sun and earth, should be at its maximum elevation whilst the earth was at its maximum depression or *vice versa*, no transit would be seen; and, even if the planet should be at its node (*i.e.*, at the mean nodal plane) and the earth be at its maximum elevation or at its maximum depression, no transit would be visible.

Fig. 26 may assist the student by making this explanation more readily apparent. In fact, Venus is more distant from the sun than one-half the distance of the earth; but since, by the theory, the deviation is proportional to the distance, the effect will actually be the same. The practical conclusion therefore, we come to, in respect to the case when a transit does take place, is that both the planet and earth are either considerably elevated above the mean (nodal) plane of the sun's equator, or are both

considerably depressed beneath that plane. . . It is for the practical astronomer to state the actual facts in this relation.

(11) SOLAR SPOTS, AND THE PERPENDICULAR-AXIS THEORY.

The nature of the theories we are here investigating suggests at once the probability that careful observations of the solar spots must at least present some evidence of value in regard to the subject under consideration, if they do not, even, furnish the means of fully determining and demonstrating which of the two theories in question actually agrees with the astronomical facts.

The following quotation from Sir John Herschel's work contains a brief record of the observations which have hitherto been made, accompanied with a statement of the interpretation attached at the present time to the meaning of the phenomena by astronomers.

Herschel's Outlines of Astronomy (page 248 to 251).

"390. When the spots are attentively watched, their situation on the disc of the sun is observed to change. They advance regularly towards its western limb or border where they disappear, and are replaced by others which enter at the eastern limb, and which, pursuing their respective courses, in their turn disappear at the western. The apparent rapidity of this movement is not uniform, as it would be were the spots dark bodies passing, by an independent motion of their own, between the earth and the sun; but is swiftest in the middle of their paths across the disc, and very slow at the borders. This is precisely what would be the case supposing them to appertain to and make part of the visible surface of the sun's globe, and to be carried round by a uniform rotation of that globe on its axis, so that each spot should describe a circle parallel to the sun's equator, rendered elliptic by the effect of perspective.

Their apparent paths also across the disc conform to this view of their nature, being, generally speaking, ellipses, much elongated, con-

centric with the sun's disc, each having one of its chords for its longer axis, and all these axes parallel to each other. At two periods of the year only do these spots appear to describe straight lines, viz., on and near to the 4th of June and 5th of December, on which days, therefore, the plane of the circle, which a spot on the sun's equator describes (and consequently, the plane of that equator itself), passes through the earth. Hence it is obvious, that the plane of the sun's equator is inclined to that of the ecliptic, and intersects it in a line which passes through the place of the earth on these days. The situation of this line, or *the line of the nodes of the sun's equator* as it is called, is, therefore, defined by the longitudes of the earth as seen from the sun at those epochs, which, according to Mr. Carrington, are respectively $73^{\circ} 40'$ and $253^{\circ} 40'$ ($= 73^{\circ} 40' \times 180^{\circ}$) for 185° , being of course, diametrically opposite in direction.

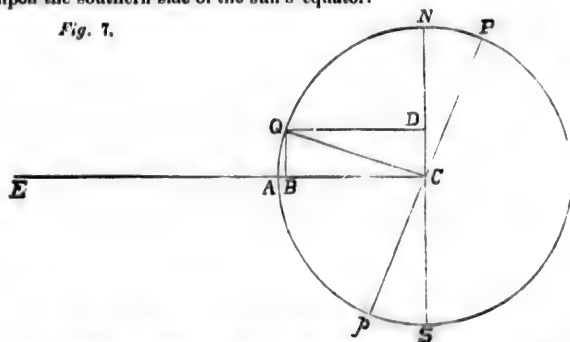
(391) The inclination of the sun's axis (that of the plane of its equator) to the ecliptic is determined by ascertaining the proportion of the longer and the shorter diameter of the apparent ellipse described by any remarkable, well-defined spot; in order to do which, its apparent place on the sun's disc must be very precisely ascertained by micrometric measures, repeated from day to day so long as it continues visible, (usually about 12 or 13 days, according to the magnitude of the spots which always vanish by the effect of foreshortening before they attain the actual border of the disc—but the larger spots being traceable closer to the limb than the smaller.) The *reduction* of such observations, or the conclusions from them of the element in question, is complicated with the effect of the earth's motion in the interval of the observations, and with its situation in the ecliptic, with respect to the line of the nodes.

For simplicity, we will suppose the earth situated as it is on the 4th of March, in a line at right angles to that of the nodes, i.e., in the heliocentric longitude $163^{\circ} 40'$, and to remain there stationary during the whole passage of a spot across the disc. In this case the axis of rotation of the sun will be situated in a plane passing through the earth and at right angles to the plane of the ecliptic.

Suppose *C.* to represent the sun's centre, *P.C.P.* its axis, *E.C.* the line of sight, *P.N.Q.A.P.S.*, a section of the sun passing through the earth, and *Q.* a spot situated on its equator, and in that plane, and consequently in the middle of its apparent path across the disc. If the axis of rotation were perpendicular to the ecliptic, as *N.S.*, this spot

would be at *A.*, and would be seen projected on *C.*, the centre of the sun. It is actually at *Q.*, projected on *D.*, at an apparent distance *C.D.* to the north of the centre, which is the apparent smaller semi-axis of the ecliptic described by the spot, which being known by micrometric measurement, the value of *C.D.* or the cosine of *Q.C.N.*, the inclination of the sun's equator becomes known, *C.N.* being the apparent semi-diameter of the time. At this epoch, moreover, the northern half of the circle described by the spot is visible (the southern passing behind the body of the sun), and the south pole *P.* of the sun is within the visible hemisphere. This is the case in the whole interval from December 5th to June 4th, during which the visual ray falls upon the southern side of the sun's equator.

Fig. 7.



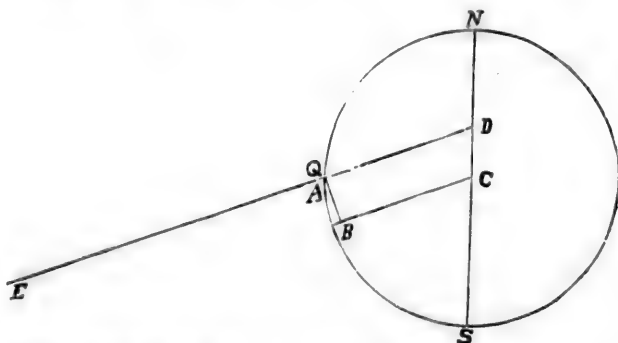
The contrary happens in the other half year, from June 4th to December 5th, and this is what is understood when we say that the *ascending* node of the sun's equator lies in $73^{\circ} 40'$ longitude—a spot on the equator passing that node being then in the act of ascending from the southern to the northern side of the plane of the ecliptic—such being the conventional language of astronomers in speaking of these matters.

(392) If the observations are made at other seasons (which, however, are the less favourable for the purpose the more remote they are from the epochs here assigned; when, moreover, as in strictness is necessary, the motion of the earth in the interval of the measures is allowed for (as for a change of the point of sight); the calculations requisite to deduce the situation of the axis in space, and the duration of the revolution around it, become much more intricate, and it would be beyond the scope of this work to enter into them. According to Mr. Carrington's determination, the inclination of the sun's

equator to the ecliptic is about $7^{\circ} 15'$ (its nodes being as above stated), and the period of rotation 25 days, 9 hours, 7 minutes; the corresponding synodic period 27 days, 6 hours, 36 minutes.*

The foregoing explanation is evidently based on an assumption that the centres of the earth and the sun are always in the same horizontal plane; or, in other words, that both of them are in the plane of the ecliptic. It is hence concluded that "if the axis of rotation were perpendicular to the ecliptic, as *N.S.* (fig. 7) this spot would be at *A.*, and would be seen projected on *C.*, the centre of the sun. It is actually at *Q.*, projected upon *D.*, &c."

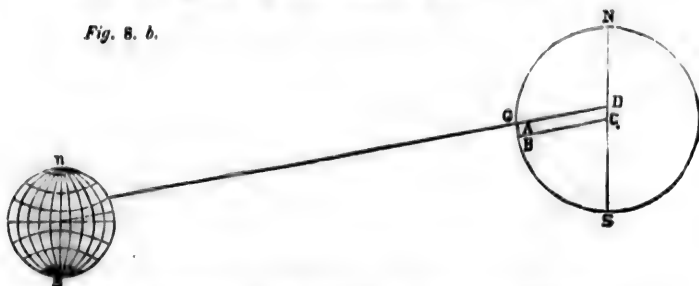
But if we repeat fig. 7, and in fig. 8 (*a*) we suppose the earth.



having its polar axis perpendicular to the plane of the ecliptic (which plane is, by the theory of the perpendicular axis, also the plane of the sun's equator, at right angles to the sun's axis of rotation), to have its centre so much below that plane that a line joining its centre to

* "These periods are those of a spot in heliographic latitude 15° N. or S. of the sun's equator. Owing to solar atmospheric drift, the periods of rotation deduced from observations of spots in high or low heliographic latitudes differ considerably."

that of the sun will form an angle (of $7^{\circ} 15'$) with that plane—the above statement will obviously no longer hold good; but, on the contrary, the sun's axis of rotation being now perpendicular to the ecliptic, the spot seen at *A*. is also actually at *Q*., (because *A*. and *Q*. now coincide,) and is projected upon *D*., as observed. It is evident that *S*., the south pole of the sun, will now occupy nearly the same position relatively to the place of the earth which was occupied by *P*., the supposed south pole in fig. 7. This is further illustrated in fig. 8 (*b*), in which the axes of the earth and of the sun are parallel to each other and perpendicular to the plane of the ecliptic; *S*., the south pole of the sun, is within the visible hemisphere, and it now appears that the point *B*., mistaken in fig. 6 for the sun's equator, is, in fact, below the equator by the distance *Q.B*.*

Fig. 8. *b*.

The distinguishing difference, however, in this connection, between the two theories is that, according to the one, the earth is rapidly and continuously ascending to a

* The difficulty and complexity belonging to the supposition of the inclined terrestrial axis is indicated in this last section of the quotation (392), in which it is stated that, if applied to (or based upon) observations made at other seasons, and if the earth's motion is allowed for, the calculations become much more intricate.

higher plane or descending to a lower plane during the twelve or thirteen days the spot remains visible...according to the other, the terrestrial observer watches the phenomena the whole time from the same undeviating plane coincident with the equatorial plane of the sun.

NOTE.—This is, however, assuming that he refers his station to the earth's centre; otherwise, by the inclined axis theory, there would be an alteration equivalent to shifting the latitude of his station to the north or to the south on the earth's surface. The effect thus caused on the apparent motion of the spots, within the twelve or thirteen days, would be very inconsiderable.....scarcely appreciable?

In § 390, Herschel notes the fact that only on and near the 4th of June and 5th of December, do the spots appear to describe straight lines. Since the inclined-axis theory, and the doctrine of the celestial spheres which belong to it, furnish no explanation of such a circumstance, it was necessary to seek an independent cause: Hence it was inferred that the sun's axis of rotation must be also inclined, at an angle of more than 7 deg. to the pole of the ecliptic.

The disorderly nature of the arrangement thus suggested, the almost frightful complication (if we may so express it,) involved therein, and . . hence, the violent improbability which belongs to such an inference, seem to have escaped notice. Whether, in considering the sun's axis of rotation relatively to that of the earth, the obliquity of the sun's position is to be considered an addition to or a deduction from that of the earth, is not, so far as we have observed, stated. We will call attention to the circumstance that, in either case, the difficulty of accepting for the earth's orbit a horizontal undeviating plane to which the earth's axis is (considerably) inclined, is yet further augmented by an inference that

the sun's axis is also (considerably) inclined to that plane.

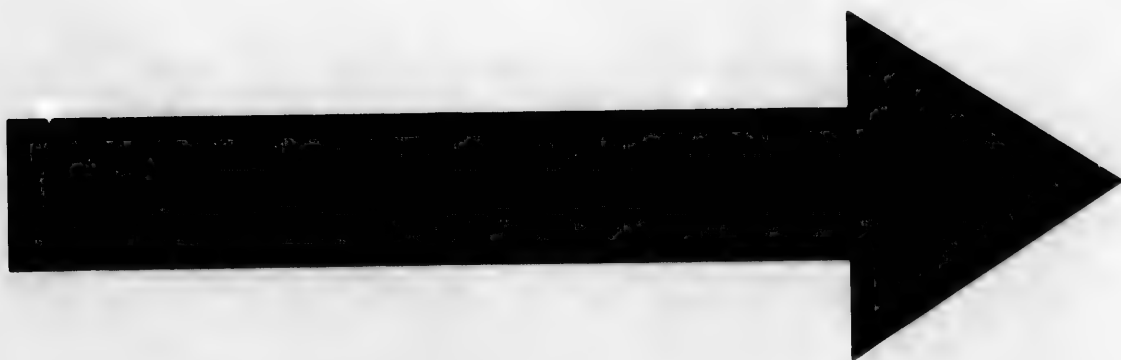
Let us now consider the perpendicular-axis theory in its relation to the particular phenomena here noted by Sir John Herschel. The *average* vertical motion of the earth during twelve days is, by that theory, about 3 deg., more when near the nodal plane, less when distant therefrom. Evidently the rapid ascent or descent, relatively to the sun, of the terrestrial observer's station, must considerably affect the apparent motion of the horizontally moving solar spots which he is watching during the successive 12 days. There are only two brief periods, during the annual revolution of the earth at (either of) which a temporary cessation of the earth's vertical motion will allow him to observe the spots move straight across the sun's disk . . horizontally or nearly so. Those two periods are (about) the beginning of June and the middle of December . . namely, at those times when the earth, having completed its descent or ascent, moves horizontally in its orbital path for a short time before recommencing its vertical motion in the opposite direction.

—

(12) THE SOLAR-SYSTEM, AND THE PHYSICAL ARRANGEMENTS OF THE STELLAR UNIVERSE.

A case which belongs as a corollary to 'the theory of the ellipticity of the planetary orbit' appears to us to have been hitherto, at least in a great measure, overlooked, and to constitute a difficulty of which the present doctrine of orbital revolution renders no satisfactory solution.

The case may be thus stated:—The earth's orbit, for example, is an ellipse . . . Now when, in connection with the present doctrine, we attentively consider this state-



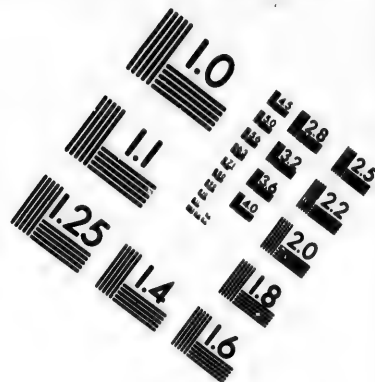
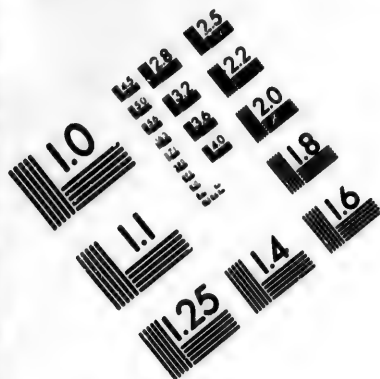
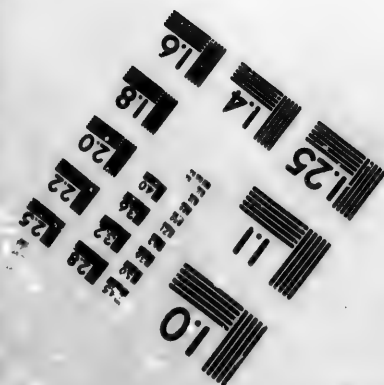
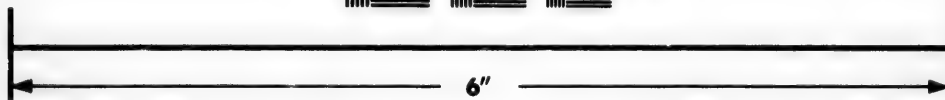
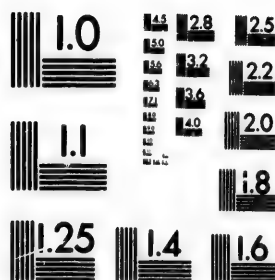


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ment of a circumstance, the evident meaning thereof is—that the earth's orbit, which would otherwise be a circle, posited horizontally, makes one great oscillation, receding away from, returning, and again advancing toward the sun, during a revolution; or, to speak more precisely, the earth being at the average distance of its orbit from the sun, recedes through a certain space to a further distance, whilst revolving around the sun, then returns again to the average distance of its orbit, and approaches nearer to the sun by a space equal to that by which it previously receded, then again returns outwards to the average distance of its orbit and performs the whole of the operation exactly in the time occupied in completing one revolution around the sun. It is in the last stated part of the case we find the difficulty alluded to. . . Why should the time of such an oscillation coincide with the time of the orbital revolution? Or, to put the question more strongly. . . How is it possible the times of the two performances can continuously coincide if the circumstances be such only as supposed by the ordinary doctrine? The two motions differ in character, for the one is a reciprocating or oscillating motion and the other is continuously progressive in the same uniform direction,—namely, at right angles to the radius of the circle in which it revolves. The only interdependence or co-relation of the motions is that arising from the relation of the law of equable areas to the law of gravitation, which has been fully explained in Part First. But this, of itself, is insufficient, for if the magnitude of the oscillation be augmented and the average velocity of motion in the orbital revolution remain unaltered, the coincidence in the times of the

oscillation and of the revolution will be disturbed and destroyed. No direct interdependence has been shown such that the one motion can be considered to restrain, control, and regulate the other, nor does any application of gravitative or other force suggest itself which could fulfil the conditions required by the present doctrine, namely, whilst restraining the revolving body from any deviation whatever above or below the orbital plane, to so control and regulate the reciprocating centrifugal and centripetal motion as to insure the continued and permanent isochronism between the complete oscillation and the complete revolution in the same plane.

The Precession of the Equinoxes.

Closely connected with the circumstances belonging to this case, is that phenomenon called the precession of the equinoxes. Now if the precession of the equinoxes were merely a retrogression of the equinoxes it might be reconciled with the present doctrine of the inclined axis, and admit of ready explanation by supposing the time of the complete orbital revolution to gain very slightly upon the time of the complete oscillation; but the so-called precession of the equinoxes includes also a corresponding and equal retrogression of the earth's aphelion and perihelion, and of the solstices. Now the solstices are by the theory of the inclined axis dependent upon the inclination of the earth's axis in space relatively to the pole of the ecliptic or to the axis of the sun considered as the standard of perpendicularity. There is, therefore, no reason shown why a progression or retrogression in the orbit of the earth's aphelion and perihelion (or of the equinoxes) should be accompanied by a similar change in the time

of the solstices. On the contrary, the fact that the alteration in the time of the one is accompanied by a corresponding and equal alteration in the time of the other goes far to demonstrate that the inclined axis theory does not furnish a true and sound explanation of the facts in this connexion. The difficulty has not been overlooked by the theoretical astronomer, but to account for it a most intricate and singular hypothesis has been imagined (devised) according to which the earth's axis and also the pole of the equinoctial travel around the pole of the ecliptic in a sort of independent supplementary orbit (of 47° diameter) with such a velocity as to require nearly 26,000 years to complete a single revolution, and which has no other apparent object than to produce and account for the precession of the equinoxes. The hypothesis seems, indeed, to be purely imaginary (notional) and unsupported; it is in a high degree objectionable because it infers a want of perfection, simplicity, and order in the work of the Creator, and is quite obnoxious to the general harmony characteristic of the dynamical arrangements pertaining to the stellar universe. *

Having briefly indicated these additional objections to the inclined axis theory, we will now revert to . . .

The theory of the perpendicular axis.

With aid of the explanations already given a little consideration will make apparent that by this theory the

* The indescribably complicated effect, compared by Sir John Herschel to "a pegtop or tee-totum when it spins not quite upright," is applied directly to the axis of the earth, which carries with it first the equinoctial circle, and then, if we apprehend aright, the whole celestial sphere, with exception of the pole of the ecliptic around which this gyratory effect takes place.

phenomenon called precession of the equinoxes is satisfactorily accounted for as a very slow retrogression of the vertical oscillation; in other words, the orbital revolution gains in time very slowly but continuously on the vertical oscillation, and completes the circle of its orbit sooner by a very minute portion of time than perfect isochronism with the vertical oscillation would admit of.*

Plates 1, 5 and 2 and, also, the figure, page 78, may be referred to in illustration of these and of the preceding remarks.

Relation of the Vertical Motion to the Compound Oblique Orbit.

We have not as yet stated or proposed any general law prescribing and limiting the quantity of that vertical motion which forms a part of the compound oblique orbit of each planet. The earth, by the theory of the perpendicular axis, ascends through $23\frac{1}{2}$ deg. above the nodal plane, and descends $23\frac{1}{2}$ deg. below that plane, together 47 deg. of vertical motion. The question is whether, in the case of planets at a greater or lesser distance from the sun than the earth, the vertical motion is proportional, directly or otherwise, to the distance.

In the absence of any astronomical investigation, that is, of subjective astronomical observation, we opine that

* If the assumption of a central sun, around which our solar system revolves in an orbit of vast extent, be tentatively accepted as scientifically reasonable . . . We then have a probable and sufficient cause to which the precession of the equinoxes may be attributed as a consequent; for the effect thereby produced would evidently be precisely of that character manifested in the precession of the equinoxes . . . to wit, a very gradual and constant gain in time by the complete revolution compared with the oscillation.

the vertical motion in the case of each planet will be found to be simply proportional to the distance of the planet from the sun: for, if the distance of a planet (the earth for example) from the sun be supposed doubled, the same decrease in the intensity of the solar attractive force which had for its consequent in the one case an increase in the magnitude of the orbit and decrease in the orbital angular velocity, will have for its consequent in the other, a proportional increase in the longitudinal magnitude of the arc of vertical motion and a decrease in the angular velocity of that motion likewise proportional.

To state that the amount of the angular vertical motion in the case of each planet is directly proportional to the distance of the planet from the sun, includes the statement, however, that the angular motion of all the planets belonging to the system is the same, or in other words, that, in the plan of the solar system, there has been allotted an equal amount of angular vertical motion to each planet, so that the angle of extreme elevation and of extreme depression is the same for all.

If it be found that this proposition is supported by astronomical fact it will immediately appear that the relation of this particular angle is of great general interest because of its selection as a part of the fundamental scale on which the dynamical arrangements of the solar system have been made. Can the astronomer declare with certainty the cyclometrical value of that angle? The reply if made hastily would be,—Yes, the angle must be 47° , because such is the vertical motion of the earth ascertained by observation, and, by the proposition, the angle is the same for all the planets.

But on considering the relation more attentively, it

appears that this angle is, in respect to a small part of it, dependent upon the perfect perpendicularity of the earth's axis throughout the vertical motion. Now there is a considerable probability that the earth may in its ascent and descent vibrate in respect to its vertical motion, that is to say, the pole of the earth may approach and recede from the pole of the sun through a small angular space, whilst the vertical motion of the annual orbit proceeds.

There are some observations recorded in astronomical works which may be found on strict examination to justify and require such modification in the theory of the perpendicular axis (*i. e.*, such modification as to include a vibration of the earth on a horizontal axis at right angles to the nodal line joining the centre of the earth and sun).

If the supposition of such a vibration be entertained, there can be no reasonable doubt as to its precise character,—namely, that as the earth ascends above the nodal plane (at which plane its position would be strictly perpendicular) the south pole and regions of the southern hemisphere, on which the sun's gravitation would act more powerfully than on the northern part of the earth, would (relatively) approach the sun, whilst the north pole, being relatively less attracted, would recede in the same ratio from the sun. When the earth, having on its return downward recovered its perfect perpendicularity at the nodal plane, descends below that plane, the conditions are reversed; the north pole and northern regions will be attracted towards the sun, and the south polar regions recede in an equal ratio. Evidently the effect of such vibration would be, by shifting

the station of the terrestrial observer relatively to the centre of the earth and sun, to exaggerate the earth's vertical motion and make the apparent angular extent of that motion greater than the actual extent thereof; and, in order to cause such exaggeration to the extent of one deg. on each side of the nodal plane... a vibration of but very small magnitude would be necessary.

Now if we may accept the supposition of such a limited and regulated vibration, the actual arc of vertical motion belonging to the compound oblique orbit will be 45 degrees. What reasonable ground have we for tentatively accepting such assumption?

(1.) That such a vibration of the earth is probable and natural; from the known relation of force and motion there must be a tendency to such vibration, and, unless entirely counteracted by the effect of the earth's rotation on its axis the tendency must result in an appreciable effect.

(2.) That various recorded observations which, although not reliable because made under misapprehension or imperfect apprehension of the actual conditions, are nevertheless entitled to consideration, appear to indicate such vibration.

(3) The probability that, from the manifest and manifold advantages in such a combination of a simple definite relation between the horizontal and vertical motions, the one would be made an aliquot and prime divisional part of the other, such as the one-fourth.*

Fig. 9 is a sectional illustration of the earth's (or other planets) vertical motion thus modified.

* That is, double the octant of 45°. Because the complete oscillation belonging to one complete orbital revolution includes one ascent and one descent, each of them throughout the extent of the vertical motion; and, therefore, the complete vertical oscillation equals the quadrant of 90°.

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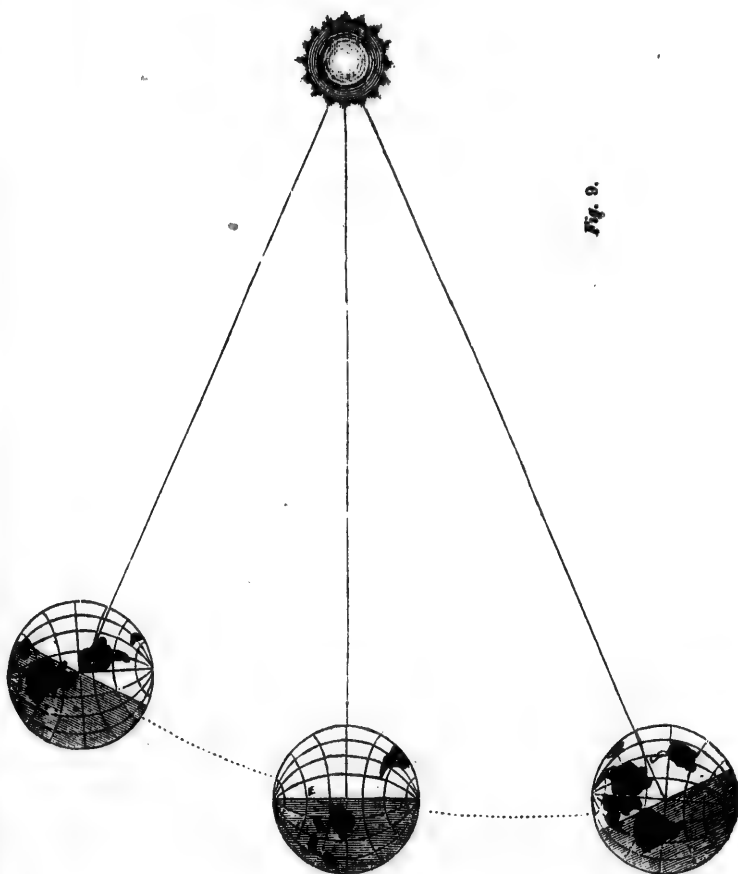
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The Astronomical Record.

Let us now, accepting the assumption of such definite relation between the vertical and horizontal motions in the compound orbit, take a brief general survey of the case thus presented to us (illustrated in fig. 9), in order to see primarily whether it appears to be supported or opposed by such direct evidences of the actual fact as the practical astronomer has as yet succeeded in obtaining.

The following quotations will suffice to bring the nature of the evidence, at present available, under the reader's immediate consideration, keeping in mind that, according to the teaching of the perpendicular-axis theory and the explanations now put before him, the observations and their record (as here quoted) are subject to that misapprehension of the actual conditions which has been pointed out.

Lardner's Astronomy. The Planet Venus.

"2691. *Direction of the axis of Rotation unascertained.*—If such difficulties have attended the mere determination of the rotation, it will be easily conceived that those which have attended the attempts to ascertain the direction of the axis of rotation have been much more insurmountable. The observations above described, by which the rotation has been established, supply no ground by which the direction of the axis could be ascertained. No spot has been seen the direction of whose motion could indicate that of the axis. It was conjectured, with little probability, by some observers, that the axis was inclined to the orbit at the angle of 75° . This conjecture, however, has not been confirmed.

The Planet Mars.

"2709. *Rotation.*—There is no body of the solar system, the moon alone excepted, which has been submitted to so rigorous and successful telescopic examination as Mars. Its proximity to the earth in opposition, when it is seen on the meridian at midnight with a full phase, affords great facility for this kind of observation.

"By observing the permanent lineaments of light and shade exhibited by the disk, its rotation on its axis can be distinctly seen, and has been ascertained to take place in 24h. 37m. 10s., the axis on which it revolves appearing to be inclined to the plane of the planet's orbit at an angle of $28^{\circ} 27'$. The exact direction of the axis is, however, still subject to some uncertainty.

The Planet Jupiter.

"2745. *Rotation and direction of the axis.*—Although the lineaments of light and shade on Jupiter's disk are generally subject to variations, which prove them to be, for the most part, atmospheric, nevertheless permanent marks have been occasionally seen, by means of which the diurnal rotation and the direction of the axis have been ascertained within very minute limits of error. The earlier observers, whose instruments were imperfect and observations consequently inaccurate, comparatively with those of a more recent date, ascertained nevertheless the period of rotation with a degree of approximation to the results of the most elaborate observations of the present day which is truly surprising, as may appear by the following statement of the estimates of various astronomers :

	H.	M.	S.
Cassini (1665)	9	56	
Silvabelle	9	56	
Schröter (1786)	9	55	33
Airy	9	55	24.6
Mädler (1835)	9	55	26.56

"The estimate of Professor Airy is based upon a set of observations made in the Cambridge Observatory. That of Mädler is founded upon a series of observations, commencing on the 3rd of November, 1834,

and continued upon every clear night until April, 1835,* during which interval the planet made 400 revolutions. These observations were favoured by the presence of two remarkable spots near the equator of the planet, which retained their position unaltered for several months. The period was determined by observing the moments at which the centres of the spots arrived at the middle of the disk.

"The direction of the apparent motion of the spots gave the position of the equator, and consequently of the axis, which is inclined to the plane of the planet's orbit at an angle of $3^{\circ} 6'$.

THE PLANET SATURN.

"2794. *Diurnal rotation.*—From observation on the apparent motion of the spots on the disk of the planet, it has been ascertained to have a motion of rotation upon the shorter axis of the ellipse formed by the disk in 10h. 29m. 17s. A terrestrial day is therefore equal to 2.3 Saturnian days.

"2795. *Inclination of the axis to the orbit.*—The general direction of the motion of rotation has been ascertained to be such, that the inclination of the equator of the planet to the plane of the orbit is $26^{\circ} 48' 40''$, and its inclination to the plane of the ecliptic is $28^{\circ} 10' 47.7''$.

"The axis like that of the earth and those of the other planets, whose rotation has been ascertained, is carried parallel to itself in the orbital motion of the planet.

"The consequence of this arrangement is that the year of Saturn is varied by the same succession of seasons subject to the same range of temperature as those which prevail on our globe."

NOTE.—The Saturnian year is equal to 29.48 terrestrial years, (10,759 days.) The seasons, therefore, do not succeed each other very rapidly if Saturn be dependent for heat and light upon the Sun only.... But there is the Ring. See Plate 7.

* These observations were made, therefore, at a time when, according to the perpendicular-axis theory, the earth was on the north side of the nodal plane, near to and at the place of maximum elevation; had the observations been continued from May to September with especial reference to any alteration in the angular position of the plane of the planet's orbit, some direct evidence would have been obtained, because the angular velocity of Jupiter's vertical motion is, by the theory, much less than that of the earth.

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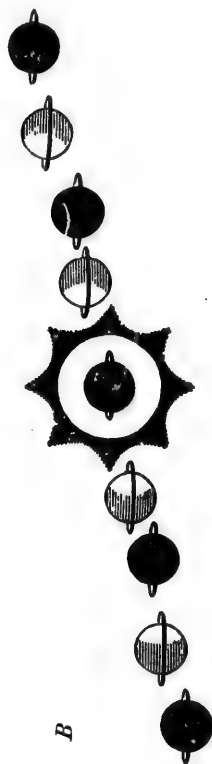
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THE PLANET
SATURN.

The diameter of Saturn is about 10 times that of the earth, and its bulk (aggregate mass) about 1000 times that of the earth.



B. Illustrating the theory of the perpendicular axis, and deviation above and below the horizontal plane of the ~~equator~~ equator.

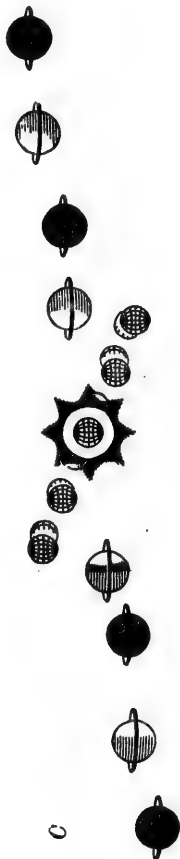


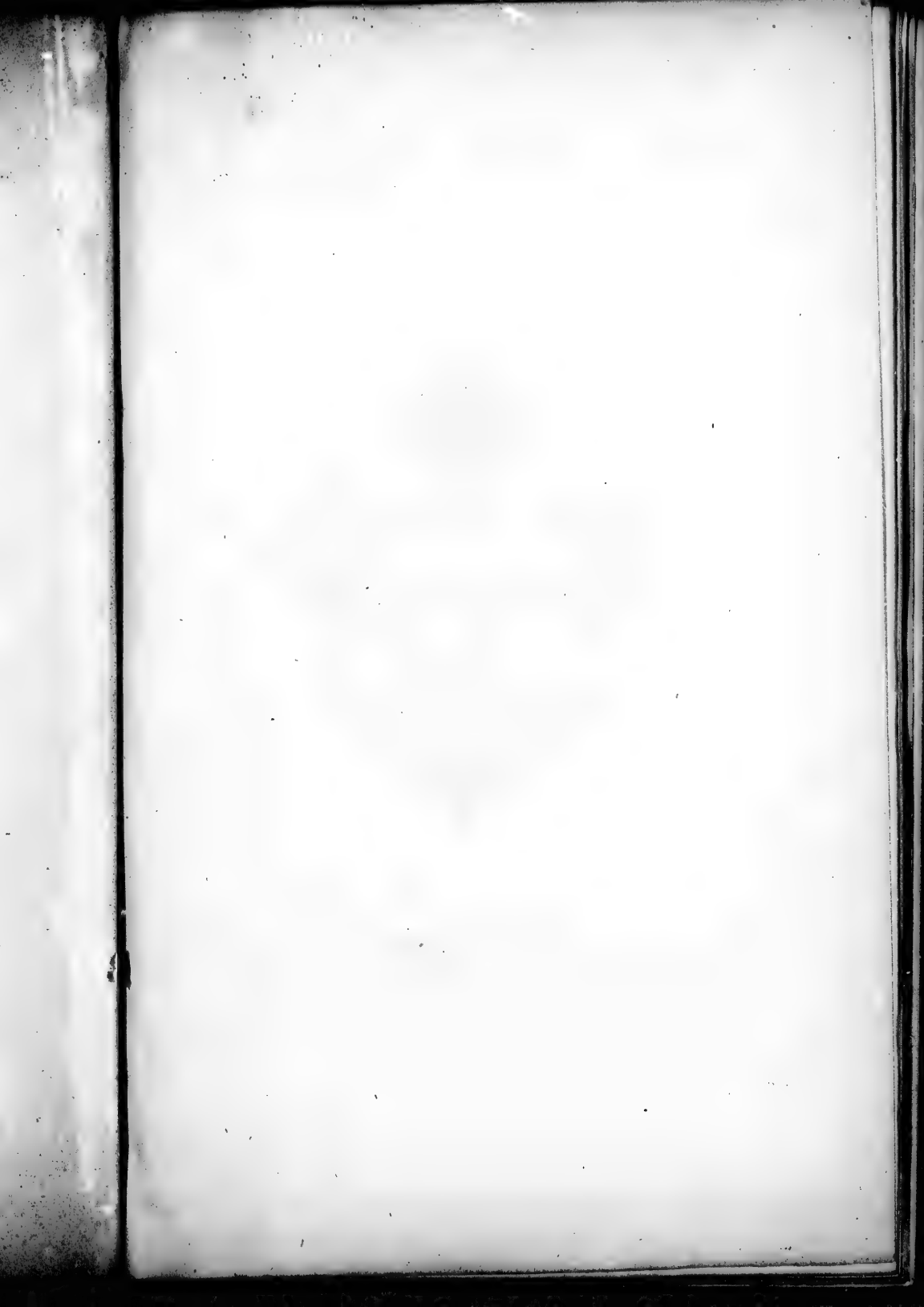
The distance of our moon from the earth is (about)
240,000 miles.

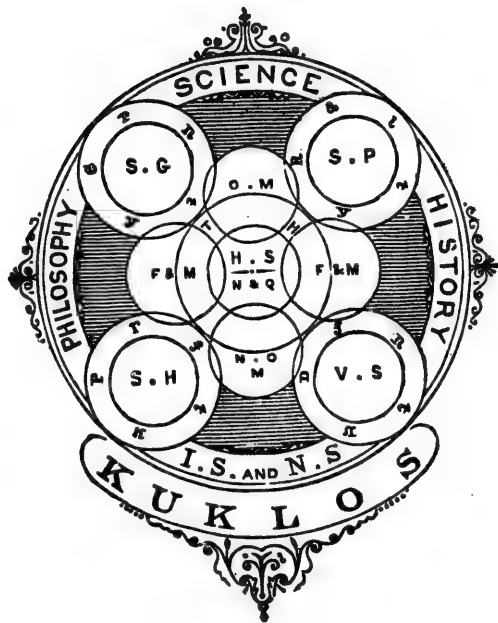
THE PERPENDICULAR AXIS.

- C. The Sun, the Earth, and Saturn.
- D. The Earth and Moon (the moon's orbit).
- E. Saturn and four satellites (the fifth omitted).

The distance of Saturn's fifth moon from that planet
is estimated at (about) 2,000,000 miles.







APPENDIX.

DEFINITIONS BELONGING TO THE PRESENT DOCTRINE CONCERNING THE CELESTIAL SPHERE AND THE INCLINED TERRESTRIAL-AXIS THEORY.

From *Herschel's Outlines of Astronomy*.

"(75) Now, so far as appearances go, it is clearly the same thing whether the heavens, that is, all space with its contents, revolve round a spectator at rest in the earth's centre, or whether that spectator simply turn round in the opposite direction in his place and view them in succession.* The aspect of the heavens, at every instant, as referred to his horizon (which must be supposed to turn with him), will be the same in both suppositions. And since, as has been shown, appearances are also, so far as the stars are concerned, the same to a spectator on the surface as to one at the centre, it follows that, whether we suppose the heavens to revolve without the earth, or the earth within the heavens, *in the opposite direction*, the diurnal phenomena, to all its inhabitants, will be no way different."

Definitions.

"(95.) Def. 12. The sphere of the heavens as of the stars is an imaginary spherical surface of infinite radius, having the eye of any spectator for its centre, and which may be conceived as a ground in which the stars, planets, &c., the visible contents of the universe, are seen projected as in a vast picture.

"(96) Def. 13. The *poles* of the celestial sphere are the points of that imaginary sphere towards which the earth's axis is directed.

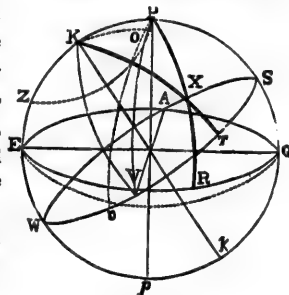
"(97) Def. 14. The celestial equator, or, as it is often called by astronomers, the *equinoctial*, is a great circle of the celestial sphere, marked out by the indefinite extension of the plane of the terrestrial equator."

* We give this extract as the first distinct expression of an implied assumption (or which includes an assumption) that the earth may be theoretically substituted for the sun as the centre of the celestial sphere. Now, if this point be ceded, one of two conclusions must follow...either, the Copernican theory must be relinquished and the Ptolemaic be upheld ;...or, the alleged fact of the obliquity of the plane of the sun's apparent path, relatively to that of the earth's orbit, and of the difference in the seasons (Summer and Winter, &c.), which is dependent upon that obliquity, must be an unfounded report; for if an upright earth revolve around the sun in a horizontal undeviating orbit, there can be no variation in the seasons.

(306) "The position of the ecliptic among the stars may, for our present purpose, be regarded as invariable. It is true that this is not strictly the case; and on comparing together its position at present with that which it held at the most distant epoch of which we possess observations, we find evidences of a small change, which theory accounts for, and whose nature will be hereafter explained; but this change is so excessively slow, that for a great many successive years, or even for whole centuries, this circle may be regarded, for most ordinary purposes, as holding the same position in the sidereal heavens.

(308) "Since the ecliptic holds a determinate situation in the starry heavens, it may be employed like the equinoctial, to refer the position of the stars to, by circles drawn through them from its poles, and therefore perpendicular to it. Such circles are termed in astronomy circles of latitude—the distance of a star from the ecliptic, reckoned in the circle of latitude passing through it, is called the *latitude* of the stars—and the arc of the ecliptic intercepted between the vernal equinox and this circle, its *longitude*. *

In the figure, X , is a star, PXR , a circle of declination drawn through it, by which it is referred to the equinoctial, and KXT a circle of latitude referring it to the ecliptic—then, as VR , is the right ascension, and RX , the declination of X , so also is VT , its longitude, and TX , its latitude. The use of the terms longitude and latitude, in this sense, seems to have originated in considering the ecliptic as forming a kind of natural equator to the heavens,† as the terrestrial equator does to the earth—the former



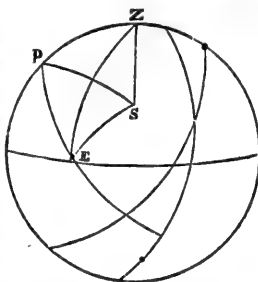
* The substitution of the perpendicular-axis theory for the present doctrine will not necessarily interfere with the employment of the actual ecliptic which is the oblique orbital path of the earth, or of the pole of the ecliptic which is the vanishing point of the extended axis of that oblique orbit, for the purposes here specified.

† It may be noted that the object of our preliminary argument in the introductory observations is to show that such definition of the ecliptic necessarily belongs to the doctrine of the inclined terrestrial axis.

holding an invariable position with respect to the stars, as the latter does with respect to stations on the earth's surface. The force of this observation will become apparent."

(310) "It is often of use to know the situation of the ecliptic in the visible heavens at any instant; that is to say, the points where it cuts the horizon, and the altitude of its highest point called the *nonagesimal* point of the ecliptic, as the longitude of this point on the ecliptic itself from the equinox. These, and all other questions referable to the same data and *quesita*, are resolved by the spherical triangle ZPE , formed by the zenith Z . (considered as the pole of the horizon), the pole of the equinoctial P , and the pole of the ecliptic E . The sidereal time being given, and also the right ascension of the pole of the ecliptic (which is always the same, viz., $18^h 0^m 0^s$), the hour ZPE of that point is known. Then,

in this triangle we have given PZ , the colatitude; PE , the polar distance of the pole of the ecliptic $23^\circ 28'$, and the angle ZPE , from which we may find, 1st, the side ZE , which is easily seen to be equal to the altitude of the nonagesimal point sought, and, 2ndly, the angle PZE , which is the azimuth of the pole of the ecliptic, and which, therefore, being added



to and subtracted from 90° , gives the azimuth of the eastern and western intersections of the ecliptic with the horizon; lastly the longitude of the nonagesimal point may be had, by calculating in the same triangle the angle PEZ , which is its complement."

The Rotation of the Earth and the Pole of the Ecliptic.

In considering generally the alteration in the relative positions of the sun, the stars, and the earth, which according to this theory, must be necessitated by the annual orbital revolution of the earth; the case is very apt to become complicated in the mind by consideration of the quite distinct effect of the diurnal rotation of the earth.

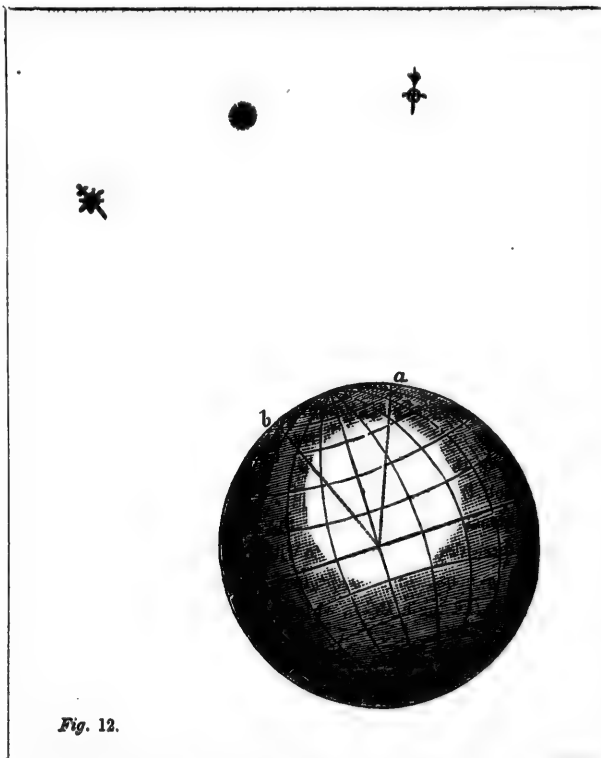


Fig. 12.

That the terrestrial place of the celestial pole, whether it coincide with the zenith place of the sun's north pole or whether it do not coincide, when once determined must be in the same case as any one of the fixed stars, is evident; and, unless it also coincide with the earth's polar zenith, must have an apparent diurnal rotation around the pole star. Although this may be quite obvious, it is nevertheless desirable

that the reader should have this comparatively simple case so distinctly apprehended as to exclude it from interference with the more complex case of the earth's orbital revolution. For this purpose we append the following illustration.

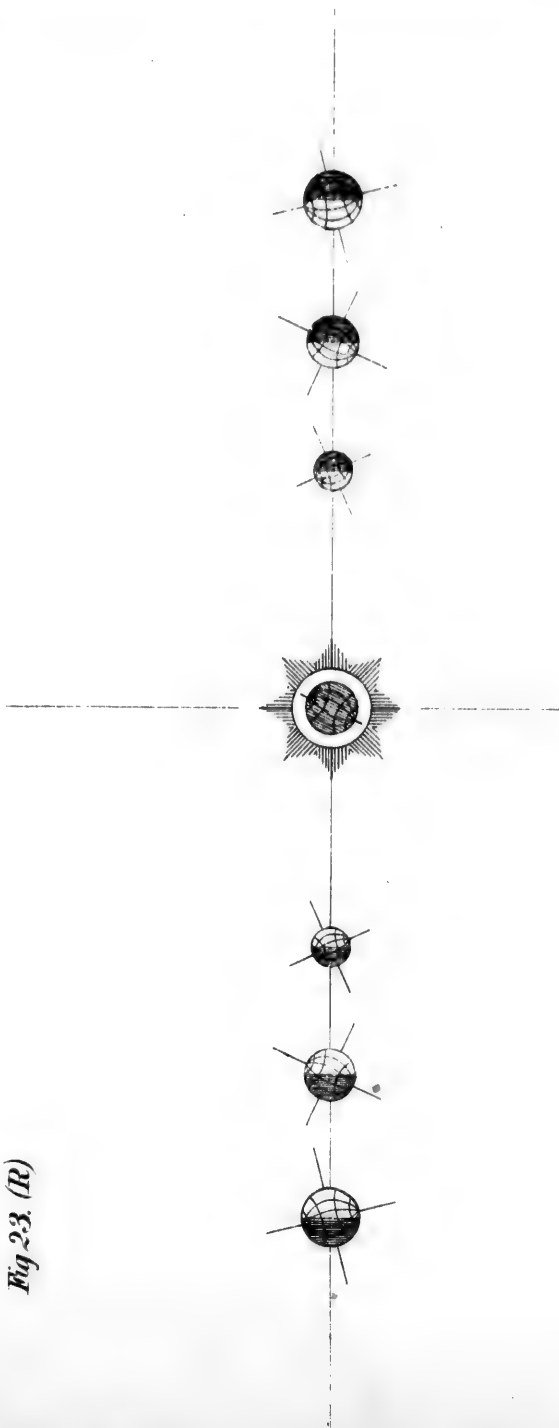
Fig. 12. Taking the star Polaris as the zenith place of the earth's north pole *... the pole of the ecliptic is a point in the heavens $23\frac{1}{2}^{\circ}$ east of Polaris. Let us suppose a station on the earth at *a*. in latitude $66\frac{1}{2}^{\circ}$ north, and longitude such that at midday an observer would have the hypothetical place of the supposed celestial pole for his zenith; at the same time he observes a star at an angular distance of 47° exactly to the west of Polaris. Making a second observation at midnight, the earth having rotated through 180° , it is evident that he will then have the star which was previously at an angular distance of 47° for his zenith, and that the supposed celestial pole will then be 47° distant, to the east of Polaris.

NOTE.—This is the simple case of the diurnal rotation of the earth considered by itself, and of which the relation to the pole of the ecliptic is the same as to any fixed star which might occupy, or may be imagined to occupy, its place. But now if we take into consideration the celestial sphere and the pole of the ecliptic as the extremity of the polar axis of that sphere, it becomes at once apparent that the theory of the inclined-axis obliges us to suppose the celestial sphere to have a diurnal reciprocating rotatory motion upon the earth as a centre; for if the pole of the sphere shifts its place from west to east and back again daily, so must the whole sphere do likewise.† The only escape from this dilemma is to suppose the earth's equatorial plane to be also the plane of the celestial equator (and such is the method now actually adopted by the practical astronomer); but this is equivalent to giving up the theory of the inclined-axis, for, in that case, since there is no obliquity of the terrestrial equator (and no vertical motion) there can be no inclination of the earth's axis.

* To simplify the explanation it is convenient so to assume: in fact, Polaris is $1^{\circ} 24'$ distant therefrom.

† In other words:—The earth's diurnal rotation carries around the terrestrial observer in the plane of the equinoctial, and (by the theory) the ecliptic is the equator of the celestial sphere, consequently the obliquity of the earth's position must continually make itself apparent in the heavens.

Fig 23. (R)



THE INCLINED-AXIS THEORY AND HORIZONTAL PLANE OF
ORBITAL REVOLUTION.

Fig. 23 R..... This figure is intended to compare with figs. 23 and 21; and also with fig. 4 *a* and fig. 4 *b*, page 37. Its purpose is to illustrate one form of the inclined-axis theory; which theory, as we have stated in the introductory observations and have shown elsewhere, is indefinite, and also inconsistent with the general doctrine of the celestial sphere, to which it belongs, in respect to certain assumptions. We have not considered it desirable to introduce this form of the theory into our general argument, because, being directly at variance with well known facts of astronomy, it is manifestly untenable: for example, in every case of either Venus or Mercury transitting the Sun, the planet would be seen to pass across horizontally on the line of the sun's equator, and, again, in every instance of conjunction, unquestionable evidence would be afforded that the orbits of the earth and planet were in the same plane, whereas the evidence is to the contrary, such coincidence being of but very rare occurrence.

Plate

Fig. 20. Illustrating:—

The Perpendicular-Axis Theory.

—o—

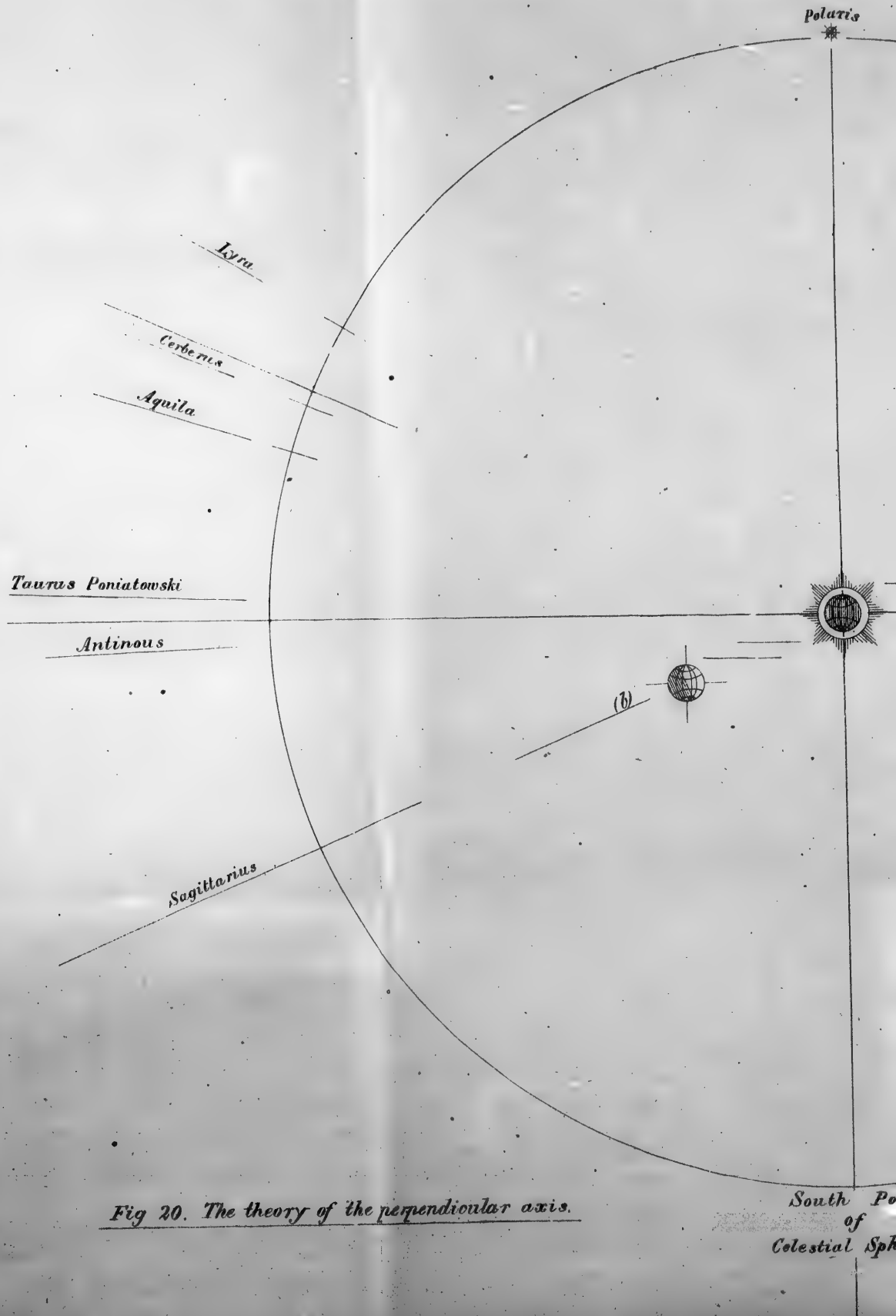


Fig 20. The theory of the perpendicular axis.

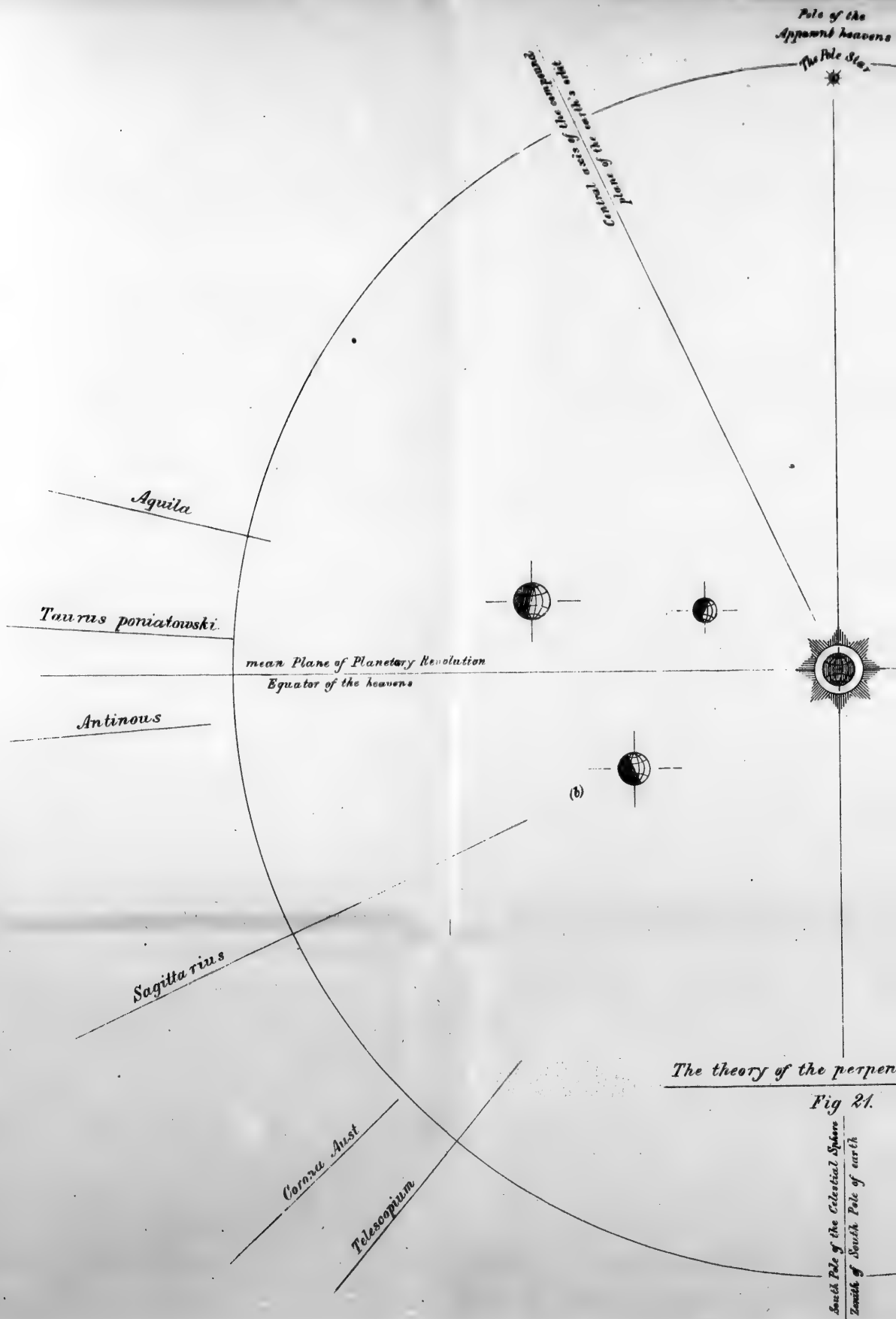


Plate

Fig. 21. Illustrating :—

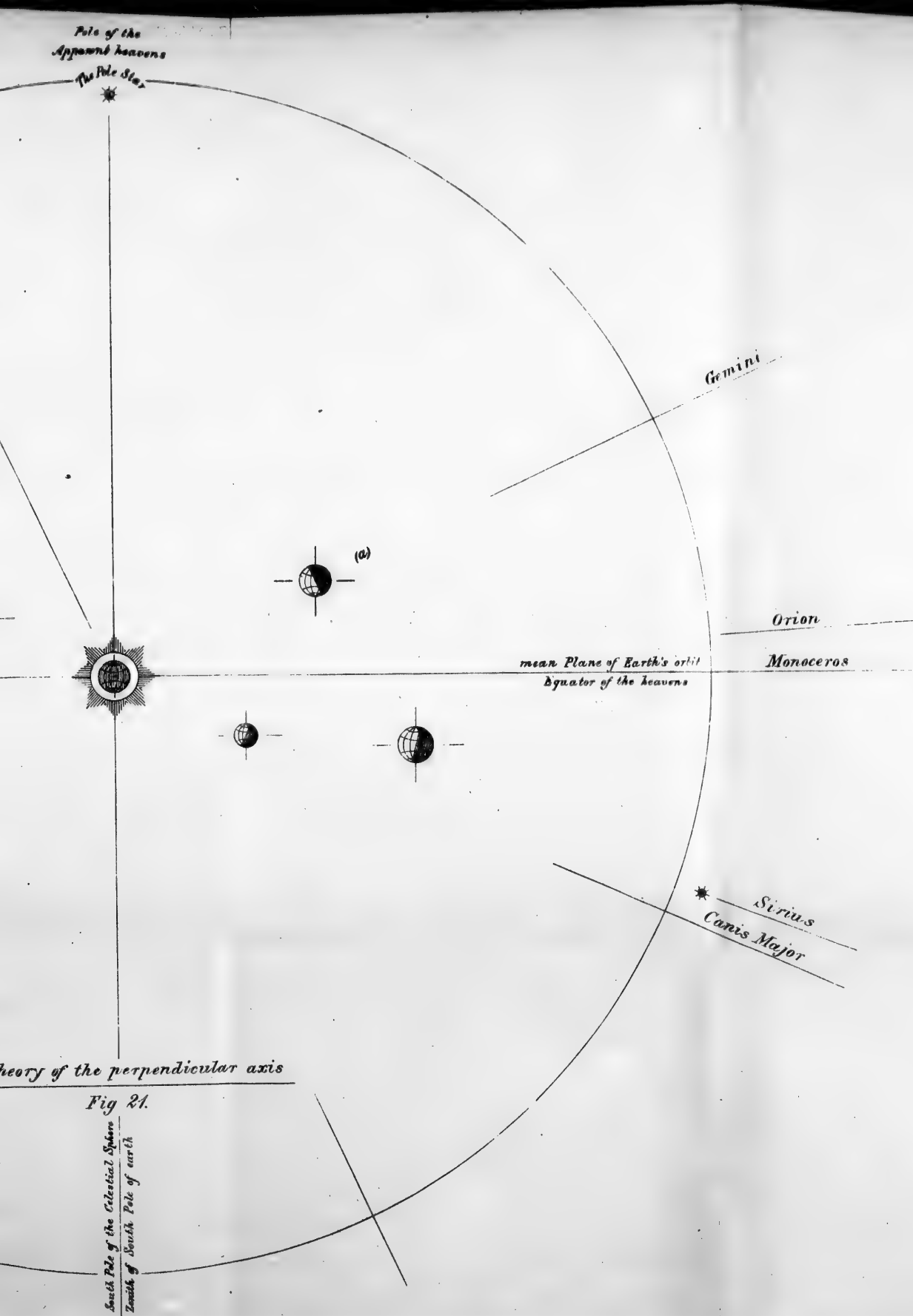
The Perpendicular-Axis Theory.

—o—



Pole of the
Apparent heavens

The Pole Star



theory of the perpendicular axis

Fig 21.

South Pole of the Celestial Sphere
Zenith of South Pole of earth

Plate

Fig. 22. Illustrating :—

The Inclined-Axis Theory.

—o—

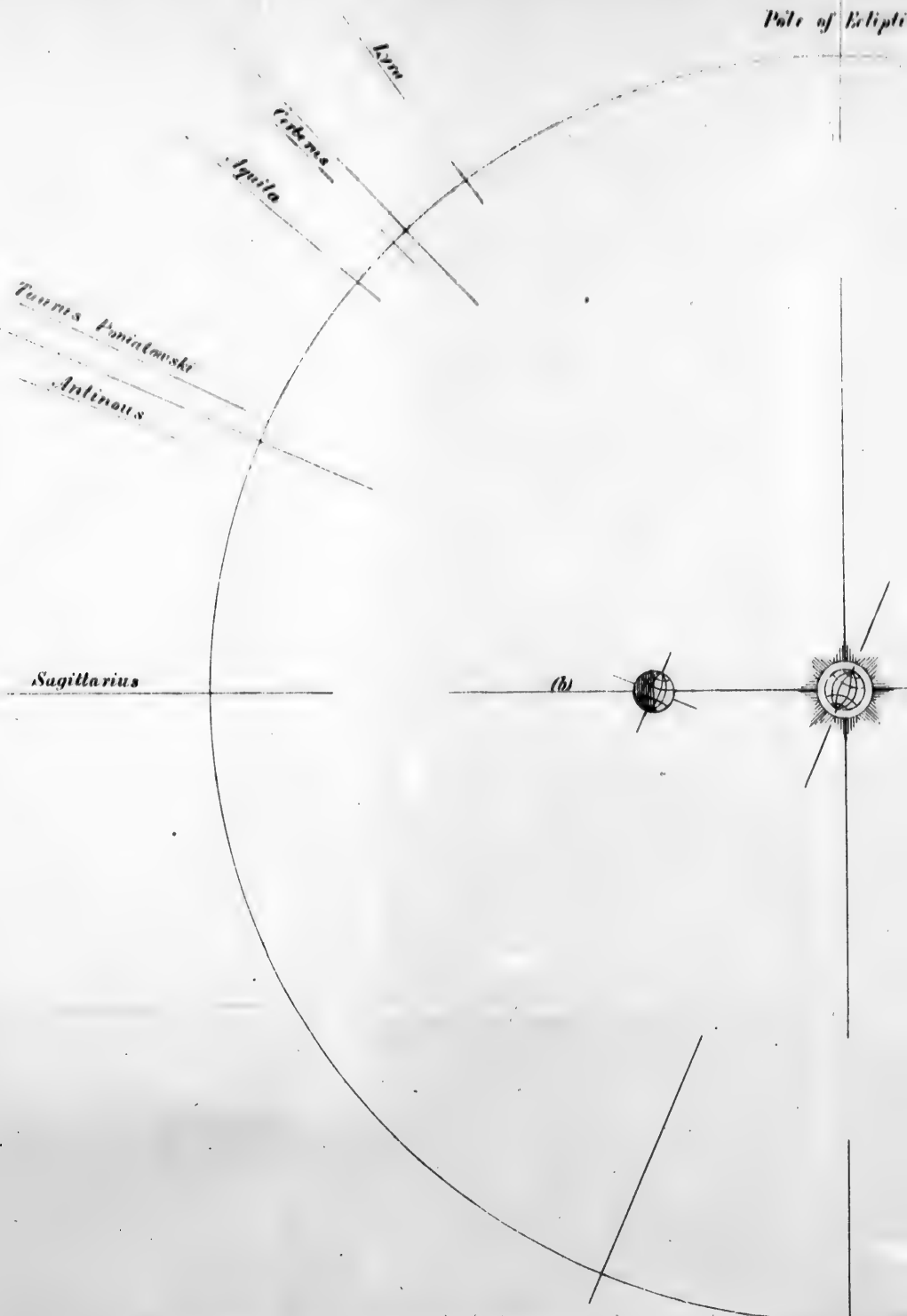


Fig 22. The theory of the inclined axis.

South Pole
of
Celestial Sphere

Pole of Ecliptic

Polaris

(α)

Gemini.

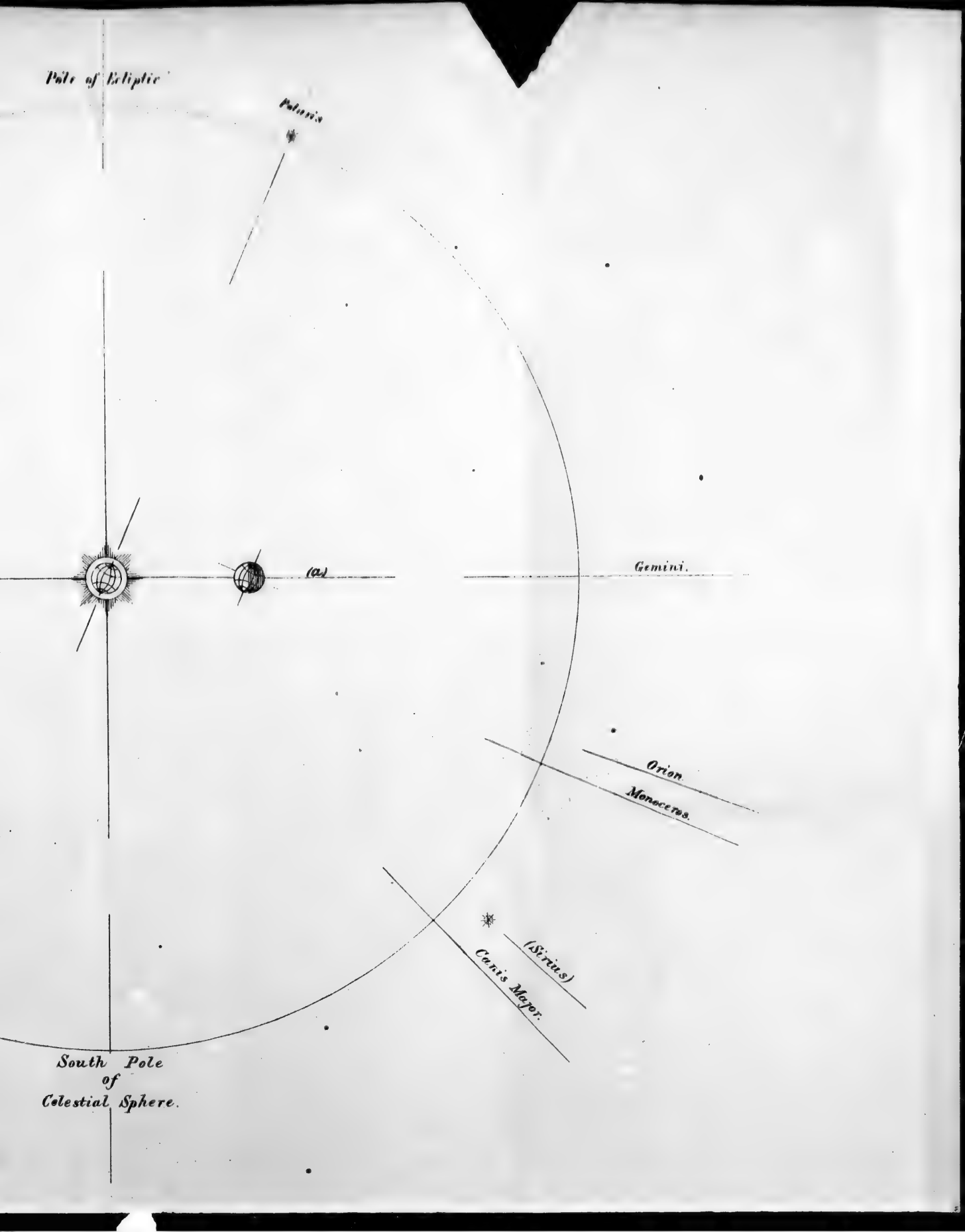
Orion.

Monoceros.

(Sirius)

Canis Major.

*South Pole
of
Celestial Sphere.*

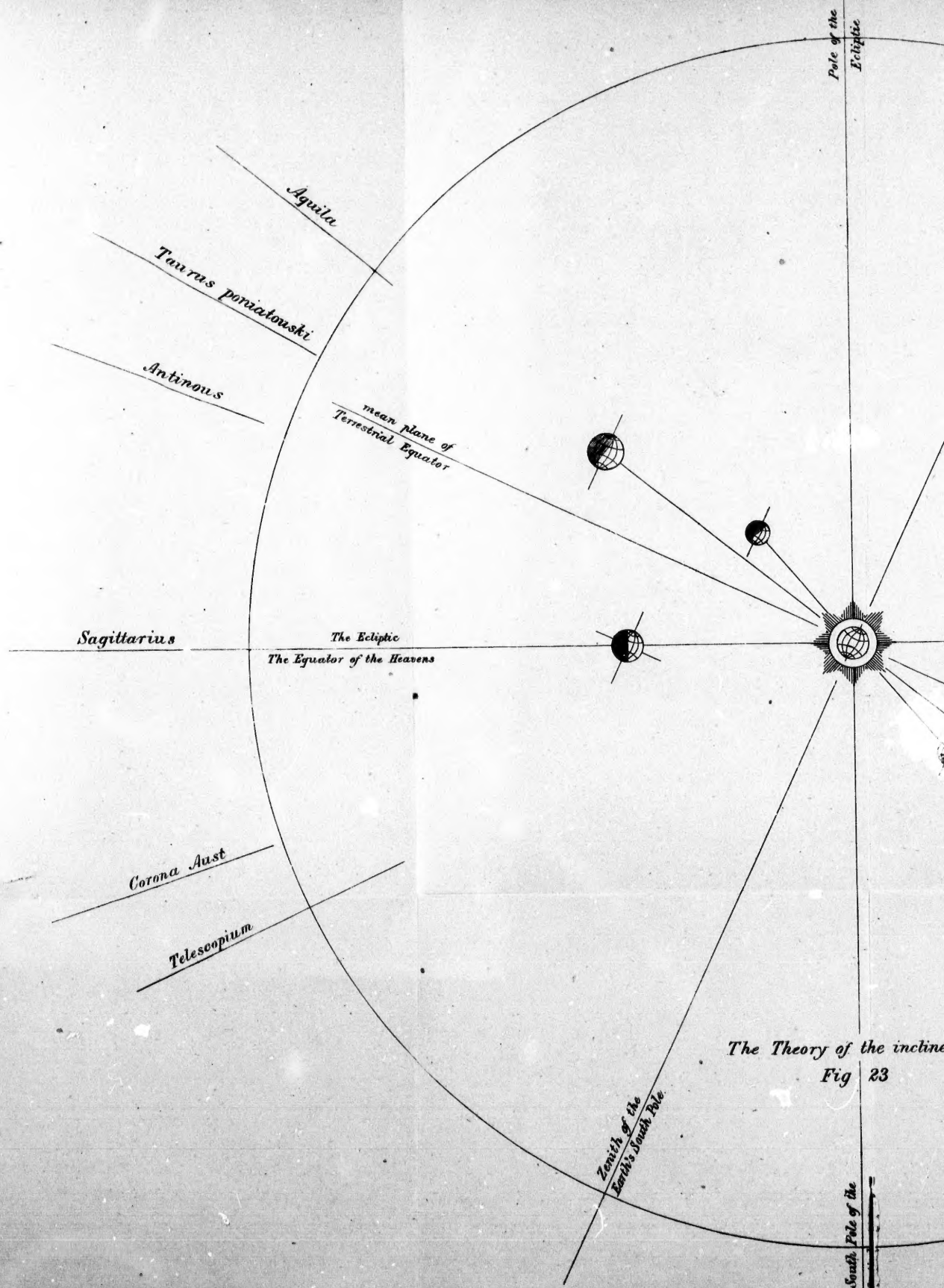


Plate

Fig. 23. Illustrating :—

The Inclined-Axis Theory.





The Theory of the inclination
Fig 23

